Dietary Intake, Nutritional Status of Lactating Women and their 6-23-Months-Old Children in *Genta Afeshum* District, Rural Ethiopia; Adaptation and Validation of Calculator for Inadequate Micronutrient Intake (CIMI)

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List of Abbreviations

AOR	Adjusted Odd Ratio
ANC	Antenatal Care
AUC	Area Under Curve
BMI	Body Mass Index
BMZ	Bundesministerium Für Wirtschaftliche Zusammenarbeit (German Federal Ministry for Economic Development Cooperation)
COR	Crude Odd Ratio
CIMI	Calculator for Inadequate Micronutrient Intake
CDI	Centre for Development Innovation
CSA	Central Statistical Agency, Ethiopia
DAAD	German Academic Exchange Service
DALYs	Disability-adjusted life-years
DDS	Diet Diversity Score
DHS	Demographic and Health Survey
DRMFSS	Disaster Risk Management and Food Security Sector
EDHS	Ethiopian Demographic Health Survey
EPHI	Ethiopian Public Health Institute, formerly EHNRI
ENA	Essential Nutrition Action
ENGINE	Empowering the New Generation to Improve Nutrition and Economic Opportunities
EOTC	Ethiopian Orthodox Tewahedo Church
ERSS	Ethiopian Rural Socio-economic Survey
FAO	Food and Agriculture Organization of the United Nations
FANTA	Food and Nutrition Technical Assistance
FFQs	Food Frequency Questionnaires
GDP	Gross Domestic Product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HDL	High Density Lipoprotein
HFIAP	Household Food Insecurity Access Prevalence
HFIAS	Household Food Insecurity Access Scale
IMF	International Monitory Fund
IYCF	Infant and Young Child Feeding
LAZ	Length-for-Age
LDL	Low Density Lipoprotein
MAD	Minimum Acceptable Diet
MDD	Minimum Diet Diversity
MDD-W	Minimum Diet Diversity for Women at Reproductive Age
MMF	Minimum Meal Frequency
MOFED	Ministry of Finance and Economic Development, Ethiopia
NBS	Nutrition Baseline Survey
NNP	National Nutrition Program
NNS	National Nutrition Strategy
NS	NutriSurvey
NSA	Nutrition Sensitive Agriculture
PNC	Postnatal Care

PCA	Principal Component Analysis
RNI	Recommended Nutrient Intake
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Science
UOH	University of Hohenheim
UNICEF	United Nations Children's Fund
UNU	United Nations University
USAID	United States of America Aids for International Development
USDA	United States Department of Agriculture
VIF	Variance Inflation Factor
WASH	Water Supply, Sanitation and Hygiene
WAZ	Weight-for-Age
WHO	World Health Organization
WLZ	Weight-for-Length

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Chapter 1

General Introduction

1. General Introduction

1.1. Background

Globally, a lot of efforts have been undertaken in reducing malnutrition, even though the achievements are far less than the global goals targeted [1]. As a result, it remains unacceptably high and a serious public health problem in the globe. This categorizes malnutrition as the leading cause for more illness than others [2]. Worldwide, the estimated prevalence of undernourished people increased from 784 million (10.6%) in 2015 to 821 million (10.9%) in 2017 [3]. However, children and women at the reproductive age are more affected by malnutrition than men. The number of stunted, wasted and overweight children under five years of age were about 151 million, 50 million and over 38 million in 2017, respectively, while about 170 million underweight and 613.2 million anemic women at reproductive age, and more than 2 billion adult overweight (1.02 billion women vs. 984.6 million men) existed in 2016 [2]. Beside these, deficiency of micronutrients affects more than 2 billion people living in this planet [4]. It is also the principal cause for the 3.5 million deaths, 11% of the total global disability-adjusted life-years (DALYs), 35% of the disease burden in young children and 20% of the maternal mortality [5]. However, the highest prevalence of undernutrition (20.4%) is registered in Africa, but the least improvement (0.8%) is shown between 2005 and 2017 [3].

Despite the high and rapid economic development achieved in Ethiopia since 2005/06, the prevalence of food and nutrition insecurity remains to be high [6–8]. The number of food in-secured Ethiopian people were about 7.8 million [9]. Since 2008, Ethiopian government has been exerting a lot of efforts to accelerate the reduction of undernutrition by developing and launching National Nutrition Strategy (NNS), and National Nutrition Programs (NNP) I and II, and fully integrating nutrition issues in the health sector program of the country [10–12]. However, the achievement is still much lower than the ambitious ‘Seqota declaration’ goal set by 2030, which is elimination of all forms of malnutrition among the children below the age of two years [13]. The recent Ethiopian demographic and health survey report showed that the prevalence of stunted, wasted, underweight and anemic children under the age of 5 years were 38%, 10%, 24% and 57%, respectively. Likewise, 22% and 24% of women between the age of 15-49 years was thin (BMI < $18.5 kg/m^2$) and anemic, respectively [6]. These burdens also co-existed with the ever increasing over-nutrition problem such as 1% overweight in children and 8% overweight or obese in women [6]. But, the distribution of the existing undernutrition problems vary by region, geographical locations, people and time [14–20]. Similar studies in three sub-Saharan African countries and Nigeria also confirmed these evidences [21,22,23]. According to UNICEF’s nutrition scale up approach for mothers and their children, inadequate dietary intake and disease are the immediate causes for the maternal and child undernutrition, which are affected by the underlying causes like household food insecurity (lack of availability, access and/or utilization of diverse diet), inadequate care and poor feeding practices for children, unhealthy household and surrounding environments, and inaccessible and often inadequate health care [24].

Food taboo is one of the socio-cultural practices in countries like Ethiopia, where more than 85 ethnic groups and different religious beliefs exist, and could affect the nutritional status of women and children [24]. Food taboos refer to those foods which are strictly forbidden for health, cultural, and religious reasons [25–31]. In different African countries including Ethiopia, food taboos are thought to have been established more often during pregnancy than other physiological stages of women, as a means of protecting the health of women and their babies. As a result, most studies in Ethiopia and other African countries focused on the exploration of food taboos during pregnancy and its association with their nutritional status and feeding practices [25,26,28,31–38]. Accordingly, some studies in Ethiopia showed that 27-60% of pregnant women are subject to food taboo [25,26,36]. They also identified that linseed, honey, dairy products, meat, eggs, fruits and vegetables, coffee, tea, porridge, wheat bread, pimento, groundnut, salty diet, nug, sugarcane, pumpkin and coca drinks were among the food items not allowed for pregnant women [25,31,36]. The main reasons for avoidance of these food items were fear of plastering on fetal head, getting a big baby which is difficult for delivery, fear of abortion, evil eye and fetal abnormality. However, lactating mothers who required greater amount of energy and most nutrients even by pregnant mothers, are also the victim of food taboo although little is known in this regard [40–42]. However, if the practice of food taboos is not identified and intervened, then it could be passed from one generation to the next generation and may sustain the intergenerational cycle of malnutrition [43,44].

Fasting is a partial or complete abstention from all foods and water or refrain from some selected and or/ prohibited foods for some fixed period of time in the year [45,46]. Religious fasting is among the different types of dietary or food taboos, which may affect the dietary intake and nutritional status of children and women. Apart from the conventional food taboos, religious fasting has a momentary nature. In these fasting periods, abstaining from animal source foods and/or water is done in the fixed period of time in the year and is a religious obligation [45].

Ramadan is in the ninth month of Islamic lunar calendar and is when Muslims fast for 29 to 30 days. In this period, Muslims are expected to abstain from eating, drinking, smoking, sexual practices and other activities for an average of 12-hrs in a day from the dawn to dusk [47,48]. Beside this, the type and amount of food to be eaten during the night of Ramadan is also significantly altered than during the rest of the year [49]. Even if fasting during Ramadan is an obligation for Muslims; pregnant women, lactating women, children, the elderly, travelers and some people with specific conditions like female at menstrual cycle or persons who cannot withstand for longer time without food or water due to some acute or chronic diseases are exempted from this practice [50,51]. However, usually breastfeeding and pregnant women and other exempted people prefer to fast with their family members to show their spiritual solidarity [50–53]. Accordingly, studies in Lebanon and Turk, pregnant women showed that the weight gain was lower in fasting compared to non-fasting groups during Ramadan [52,54]. Similarly, the % of recommended daily allowance of most nutrients fulfilled by the Turkish pregnant women who were fasting were lower compared to those pregnant women who did not [54]. The cohort study in Lebanon also showed that the mean birth weight of the women who fasted during their pregnant period were significantly lower than the average mean birth weight of the women who did not fast during their pregnancy period. Likewise, a study on Turkish lactating women confirmed that the nutrient quantity of the breast milk and weight and their child's weight were lower in Ramadan fasting period than after one month non-fasting period [53]. A study on patients with a cancer-related fecal stoma revealed that the weight loss after Ramadan fasting was about 9.5kg compared to the time right before Ramadan [50]. A systematic review and meta-analysis in West Asia, Africa, East Asia and North America/Europe confirmed that the weight loss was significantly higher, regardless of gender, but this loss was regained within a few weeks after Ramadan [48].

In Orthodox Christian religion, followers are expected to fast for at least 180 days in a year [46,55–58]. Fasting includes abstention from all animal source foods (meat, milk, butter and eggs), but restriction of fish in Ethiopian Orthodox church is not uniform [45]. Studies in Greek Orthodox Christian monks revealed that the consumption of dairy products, meat and eggs, and the dietary intake of calcium, and BMI were lower in fasting weeks compared to week following fasting. However, the profile of individual health biomarkers like total cholesterol, LDL-cholesterol and HDL-cholesterol in serum were lower during fasting than non-fasting weeks [60]. Annual longitudinal study on 120 Greek Orthodox Christians (60 fasting vs. 60 non-fasting as control) also confirmed that a significant reduction in the total and LDL-cholesterol, and BMI was observed in an end line survey compared to control group [59]. Similar authors in the Greek Orthodox followers also evidenced that the dietary cholesterol, protein, energy and calcium intakes were also low in fasting groups compared to the control in the end-holidays than pre-fasting period [57]. Two review papers focused on the health related impact of Orthodox fasting also confirmed that BMI, lipid profile including cholesterol level of fasting individuals decreased, and these improved their health status [46,61]. Relatively, a recent systematic review on the effect of Orthodox fasting on human health confirmed that few researches were conducted in this specific topic. But the results of these studies indicated that the total energy and fat intakes are restricted, but carbohydrate and fiber intakes increased. Beside this, the overall effect of Orthodox fasting on reduction of total cholesterol and LDL-C levels were somewhat optimal. According to Kaufakis and colleagues, studies on the impact of Orthodox fasting are limited, but these studies are also conflicting with each other's, as a result a consensus has not been reached to draw conclusion. Therefore, further study on this regard is recommended [62]. In general, many of the researches focused on the effect of fasting on human health specifically chronic diseases. However, knowing the fasting effect on dietary pattern and nutritional status in countries with high prevalence of maternal and child undernutrition is very important.

Follower of Ethiopian Orthodox and Muslim religion make up to three-fourth of people in Ethiopia, who practice a strict fasting during their religious fasting periods [63]. But, their fasting practices including number of fasting days, type of fasting, number of fasting hours and type of food items restricted are some of the differences between this two religions [64]. According to Ethiopian Orthodox church rule, there are seven official fasting periods and a total of these periods cover approximately 250 out of 365 days in a year. In these days, children less than seven years old, soldiers, severely ill or weak people, pregnant, and lactating mothers are permitted to eat both animal source foods and other foods including water, without abstention during the religious fasting periods or days [45,58,65]. However, little studies in Ethiopia highlight the religious fasting in relation with feeding practices and nutritional status in nutritionally vulnerable groups (women and children) who are the follower of the two dominant religion. Despite these nutritionally needy groups (lactating and pregnant mothers, and children) who are exempted from the religious fasting, yet the consumption of animal source foods during the fasting periods are very low for different reasons [43,66]. For example, studies in Amhara and Tigray regions explored that some mothers were not happy to prepare food for their children from animal sources due to fear of utensils contamination during cooking family food, and this reason increased the likelihood of feeding less diverse food for their children by 1.5 times compared with the economic related reasons [44,67,68]. Other studies in Ethiopia also showed that the demand of cattle meat during Orthodox fasting periods was observed to be low, resulting in closure of abattoirs or minimizing the service provided. A further study also reported that more than 85% of butcher houses were closed during Wednesday and Friday, which are Orthodox Christians fasting days of the week, in Addis Ababa, a capital city of Ethiopia [70,71].

The first 1000 days of life, between the conception of a woman until her child celebrates his/her two years' birthday, is a critical window of opportunity to build a foundation for optimal health and development, and success for the child across his/her life time. Proper nutrition and care during this window period improve the survival rate, his or her growth and learning ability, and later contribute to societies long term health, stability and prosperity [72]. A mother's diet and her nutrient stores are the only source of nutrition for the developing baby in her womb. When a pregnant woman does not get the calories, key nutrients or essential proteins she needs to support her baby's development, her baby is placed at risk for developmental delays, birth defects and cognitive deficits [73]. Undernutrition in pregnant women increase the risk of maternal morbidity and mortality and also prone to poor pregnancy outcome, which include obstruction during labor, preterm or low birth child and postpartum hemorrhage [74]. Beside this, folate is critical to the early development of the brain and spinal cord of the fetus. When a woman lacks this before becoming pregnant and in the early weeks of her pregnancy, the development of the neural tube is affected, leading to birth defects of the brain and spinal cord (anencephaly and spinal bifida) that can cause death or lifelong disability [73]. Lactation is the second physiological stage, which cover three-fourth of the 1000 window days. Even except iron and folate, energy and most micronutrients need of lactation is greater compared to pregnancy [40,42,75–77]. During lactation, the energy, macro- and micronutrients in breast milk come from the mother's diet and/or her own body stores, which make the lactating women in high risk of malnutrition unless she consumes adequate nutrient and energy rich foods [51,53]. The quality of breast milk could be altered, as a result the nutritional status of the breastfed child could also change [51,78]. Furthermore, if the lactating mother is severely malnourished, then her lactation performance will decrease and contribute to child morbidity and mortality [79].

Exclusive breast feeding during the first six months after delivery and continued breast feeding up to one to two years in combination with introduction of appropriate, adequate and safe complementary feeding are among the recommended IYCF practices [80]. Appropriate complementary feeding can prevent about 6% of deaths of under-five aged children [5,81]. The transition period from exclusive breastfeeding to two years is critical for optimal growth and development of a child [81]. The prevalence of "ever breastfeeding" in rural Ethiopia was about 97.8% versus 95.2% of recommended IYCF practices, which is a positive practice [82,83]. Likewise, many rural mothers continue breastfeeding until their child reaches the age of at least 24 months and in some cases even for a longer time. According to national study in Ethiopia, 76% of 2 years old children were continually breastfed [6]. Previous studies in Tigray, northern Ethiopia showed that 25% of the children were breastfed for more than 3 years [84]. Therefore, assessing the dietary adequacy of energy, macro- and micronutrients is very useful in the whole population groups specially children and women. For this, a number of both qualitative and quantitative dietary assessment techniques have been developed and implemented globally. However, most of the quantitative dietary nutrient intake assessment techniques like food frequency questionnaire (FFQs), food weight record and 24-h recall are time consuming, need well trained field workers during the surveys and an expert to calculate dietary intake using nutrition software and identify undernutrition. Therefore, the application of these methods has been less in rural poor settings in developing countries including Ethiopia. Alternatively, many assessment and intervention studies use a qualitative method known as diet diversity scores, which is a proxy indicator for assessing the dietary quality at household and individual levels [85]. Accordingly, national and different studies, elsewhere in Ethiopia showed that the consumption of foods from different food groups in children and women (pregnant, non-pregnant-non-lactating, and lactating women) were low [40,81–83,86–88]. However, this technique identifies the score of the consumption of diet from different standardized food groups regardless of the amount consumed, as this technique doesn't allow the serving size ideally. Therefore, unless small amount of consumption is excluded in the count, then the validity of the

DDS will be in question. For this, many scholars suggested that consumption of at least 15 g from the group should be the minimum to be considered as consumed in women at reproductive age, otherwise the relationship between food group diversity and micronutrient adequacy is weaker [85,90–92]. As a solution, defining the food and ingredients to count and not to count during the construction of the questionnaire for MDD-W indicator should be done, and during the training of enumerators to avoid biased-decisions [85]. But, still the controversy remains on how quantification is practical in qualitative diet diversity assessment technique, unless the diet diversity data is extracted from other quantitative dietary intake data. Minimum acceptable diet, which is a combination of minimum diet diversity and minimum meal frequency is used to assess the quality and quantity of children's diet, in addition to other IYCF indicators [80]. Many studies at district and national levels in Ethiopia confirmed that the proportion of 6-23-months-old children who met the minimum number of meals from minimum diversified complementary food for their age and breastfeeding was very low (<10%) [6,43,93,94].

Human being needs, both nutrients which is called macronutrients (fat, protein and carbohydrate) and micronutrients which are needed in small amount, but are important for the metabolic process and function of the macronutrients are necessary [4,95]. Unlike macronutrients, micronutrients neither substitute each other nor are synthesized in our body. Therefore, supply of these nutrients through our diet is mandatory, although the amount required differ due to age, life style, hormonal activity or exercise and bioavailability related with food to be consumed [4]. If these micronutrients are inadequate, it leads to the invisible form of undernutrition called micronutrient deficiency or 'Hidden hunger'. If it persists for some longer period will increase the risk of disease, growth and cognitive development impairment in the early stage of childhood, and later maternal illness and decrease the life expectancy. Thus, early identification of micronutrient deficiencies will be an important step to design and initiate appropriate prevention and intervention activities [96]. However, these are flouted, as the quantitative dietary data are not available most often [2]. As a result, the hidden hunger might not be addressed properly in Ethiopia and other African countries, where this occurrence remains high and persistent [2,6]. Therefore, an assessment tool which can estimate the quantitative dietary intake of an individual or a community, but easy to use, less costly and applicable method for developing countries including Ethiopia is urgently needed to achieve the national and international goals set for eradicating malnutrition. The Calculator for Inadequate Micronutrient Intake (CIMI) is a simple, easy-to-use, informative, web-based application of quantitative dietary assessment method. The first version of CIMI was developed in Indonesia using commonly consumed Indonesian foods for Indonesian population. Thus, CIMI estimates energy and nutrient intake correctly, and identifies nutrient inadequacy according to FAO/WHO recommended nutrient intake (RNI) regarding age, sex and physiological stage [96].

Genta Afeshum is one of the thirty-five district's in the Tigray regional state in Ethiopia. According to CSA (2007) projection, the district has a total population of 99,112, and almost all (99%) people are Orthodox Christianity follower. The district is known with cultivation of majorly cereals, followed by pulses, oil seeds, fruit trees and vegetables in decreasing order of importance. Of these, wheat, barley, legumes, maize, fenugreek, teff, sorghum and orange fleshed sweet potato are mentionable. However, Genta Afeshum is one of the hotspot districts for food insecurity in the region. It is also known with major disaster risks like drought, hail storms and livestock diseases; followed by human diseases, crop diseases and pests and flooding. Deforestation, water pollution and soil erosion are the major environmental problems; whereas, high dependency syndrome, poor economic condition, land shortage, severe shortage of drinking water and poor saving are among the major vulnerability factors at household level [97]. But, to the best of our knowledge, there was no study which assessed the dietary pattern and nutritional status of women and children in Genta Afeshum district.

Therefore, the purpose of this study was assessing and comparing the nutritional status and dietary intake of lactating women and their 6-23months old children in fasting and non-fasting periods at Genta Afeshum District, rural Tigray in Northern Ethiopia, and to develop and validate the CIMI program for Ethiopian population. For this, the following specific objectives were set to address the three papers written as chapter two, three and four of this Dissertation,

1. Assessing and comparing the nutritional status of lactating mothers and their 6-23-months old children in Ethiopian Orthodox lent fasting and non-fasting periods in Genta Afeshum district, Rural Tigray, Ethiopia.
2. Assessing factors associated with undernutrition (BMI$<18.5kg/m^2$) in lactating mothers of Genta Afeshum district, Rural Tigray, Ethiopia.
3. Assessing factors associated with undernutrition (stunting, underweight and wasting) in 6-23-months old children of Genta Afeshum district, Rural Tigray, Ethiopia.
4. To compare dietary pattern of lactating mothers and their 6-23-months old children during fasting and non-fasting periods in Genta Afeshum district, Rural Tigray, Ethiopia.
5. To adapt CIMI program and compare with NutriSurvey for its ability to analyze dietary nutrients and energy intakes in Genta Afeshum district, Rural Tigray, Ethiopia.

1.2. Outline of the thesis

This Thesis/Dissertation has six chapters and the biography at the end. Chapter 2 of this Thesis/Dissertation is entitled ''Ethiopian Orthodox Fasting and Lactating Mothers: Longitudinal Study on Dietary Pattern and Nutritional Status in Rural Tigray, Ethiopia ''. The chapter focused on identifying underweight (BMI < 18.5kg/m^2) and food consumption pattern of fasting and non-fasting mothers in Ethiopian Orthodox lent fasting and non-fasting periods. It also identified whether there was a difference in each food groups consumed, diet diversity and animal source consumption score, and anthropometric status between the lent fasting and non-fasting periods, separately for fasting and non-fasting mothers. For this, McNemar's test and Wilcoxon Signed Ranks Tests were used to check the statistical difference. Furthermore, the chapter addressed the factors associated with the underweight of lactating mothers in the study area. The factors included in the logistic regression to identify associated factors were from the socio-demographic and economic characteristics, maternal and child characteristics, water, sanitation and hygiene (WASH), feeding practices and household food security indicators. The underlying publication was published in *International Journal of Environmental Research and Public Health in 2018, Vol 15(8), page 1-20*.

Chapter 3 of the Thesis dealt with ''Feeding Practices and Undernutrition in 6–23-Month-Old Children of Orthodox Christian Mothers in Rural Tigray, Ethiopia: Longitudinal Study''. Like chapter 2, this chapter focused on differences in the consumption pattern between the general 6-23-months-old children in the lent fasting and non-fasting periods, regardless of their mothers fasting status, and separately both for the 6-23-months-old children of the fasting and non-fasting mothers. It also highlighted differences between mean standard deviations of length-for-age, weight-for-length and weight-for-age z-scores between children of fasting and non-fasting mothers during lent fasting period. It also stressed on the trend of the weight for age and diet diversity score of the whole population between the lent fasting and non-fasting periods. On top of these, the prevalence of child undernutrition (underweight, wasting and stunting) and associated factors were also addressed. McNemar's test, independent sample t-test, Wilcoxon Signed Ranks Tests and binary logistic regression were used to analyze the data. This article was published in *nutrients in 2019, Vol 11, page 1-15.*

Chapter 4 holds a paper 'Dietary Nutrient Intake of 12-23-Months-Old Children and Lactating Women in Rural Ethiopia; Adaptation and Validation of Calculator for Inadequate Micronutrient Intake (CIMI)' and was submitted also to *nutrients* journal in May 22, 2019. It focuses on two major issues. The first part was on the development of simple and rapid app for assessment of dietary nutrient intake using commonly consumed Ethiopian food items for Ethiopian population, followed by assessing the validity of the results produced by this software compared to internationally established nutritional assessment software called NutriSurvey. The second part of this chapter focused on identifying the estimated dietary energy and nutrient intakes and the prevalence of inadequacy of the 12-23-months-old children and lactating mothers during the lent fasting and non-fasting periods. Statistical analyses were done using descriptive statistics and Pearson correlation test to check the relationship of the results produced by CIMI and NutriSurvey, of each nutrients and energy for the 12-23-months old children and lactating women.

In chapter 5, the results presented in the three chapters (2, 3 and 4) are merged and discussed together. In this discussion, recent evidences in relation with the dietary pattern and nutritional status of children and women; in regard to religious fasting were found and compared and argued with/against our findings. Additionally, the development of CIMI software, and the assessment of its validity compared to NutriSurvey as a reference are discussed with previous findings in the CIMI software developed for other countries, and other dietary assessment tools in its applicability. At the end of this chapter, the general conclusion drawn from the whole research findings in this study are presented.

Chapter 6 encompasses the general summary of the whole findings in the Thesis/Dissertation and is presented in both German and English languages.

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Chapter 2

Paper I

2. Ethiopian Orthodox Fasting and Lactating Mothers: Longitudinal Study on Dietary Pattern and Nutritional Status in Rural Tigray, Ethiopia

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Ethiopian Orthodox Fasting and Lactating Mothers: Longitudinal Study on Dietary Pattern and Nutritional Status in Rural Tigray, Ethiopia

Abstract

About half of Ethiopians belong to the Orthodox Tewahedo religion. Annually, more than 200 days are dedicated to religious fasting, which includes abstaining from all types of food, animal source foods, and water. However, the association of fasting with undernutrition remains unknown in Ethiopia. Therefore, dietary pattern and nutritional status of lactating women during lent fasting and non-fasting periods were studied, and predictor variables for maternal underweight were identified. To achieve this, lactating mothers in lent fasting (N = 572) and non-fasting (N = 522) periods participated from rural Tigray, Northern Ethiopia. Average minimum diet diversity (MDD-W) was computed from two 24-h recalls, and nutritional status was assessed using body mass index (BMI). Binary logistic regression was used to identify potential predictors of maternal underweight. Wilcoxon signed-rank (WSRT) and McNemar's tests were used for comparison of the two periods. The prevalence of underweight in fasting mothers was 50.6%. In the multivariate logistic regression model, younger age, sickness in the last four weeks preceding the survey, fasting during pregnancy, lactation periods, grandfathers' as household decision makers, previous aid experience, non-improved water source, and not owning chicken were positively associated with maternal underweight. In WSRT, there was no significant ($p > 0.05$) difference on maternal body weight and BMI between periods. The average number of meals, diet diversity, and animal source foods (ASFs), consumption scores were significantly increased in non-fasting compared to fasting periods in both fasting and non-fasting mothers ($p < 0.001$, p

< 0.05, and $p < 0.001$, respectively). Consumption of dark green leafy vegetables was higher in the fasting period (11%) than non-fasting (3.6%), in the study population. As a conclusion, Ethiopian Orthodox fasting negatively affected maternal nutritional status and dietary pattern in rural Tigray, Northern Ethiopia. To reduce maternal malnutrition in Ethiopia, existing multi-sectoral nutrition intervention strategies, should include religious institutions in a sustainable manner.

Keywords: lactating mothers; Ethiopian Orthodox lent fasting; ASFs consumption; underweight; Ethiopia

2.1. Introduction

Undernutrition is a serious public health problem worldwide. It is the underlying cause for 3.5 million deaths, 35% of the disease burden in children younger than 5 years old, 11% of total global disability-adjusted life-years (DALYs) and accounted for at least 20% of maternal mortality [1–4]. According to Food and Agriculture Organization of the United Nations (FAO) estimates, the global prevalence of chronically undernourished people increased from 777 million (10.6%) in 2015 to 815 Million (11%) in 2016; however, the deterioration was most severe in sub-Saharan Africa. Eastern Africa is one of the four sub-regions in sub-Saharan Africa, where one-third (33.9%) of the population was estimated to be undernourished in 2016 [3].

Good nutritional status of women is important for their good health and working capacity, as well as for the health of their offspring [1]. During pregnancy and lactation, women are more vulnerable to undernutrition than others at reproductive age, due to increased energy and nutrient requirements [5–7]. Globally in 2011, the prevalence of anemia in pregnant women was 38.2% vs. 29% in non-pregnant women [8]. According to the Demographic and Health Survey (DHS) in Ethiopia, the prevalence of anemia in pregnant or lactating women (19% and 29%) was higher than in non-lactating-non-pregnant women (15% and 21%) [DHS 2011, 2016, respectively] [9,10]. Likewise, the prevalence of underweight (BMI < 18.5 kg/m^2) in lactating mothers was 25–55%, which was higher than non-pregnant-non-lactating women (22%) [5,9–12].

Food taboos refer to those foods which are strictly forbidden for health, cultural, and religious reasons [13–16]. In Ethiopia, food taboos are thought to have been established during pregnancy as a means of protecting the health of women and their babies. As a result, scholars in Ethiopia focused on the exploration of food taboos during pregnancy and its association with their nutritional status and feeding practices [15–18]. However, lactating mothers who even need more nutrients than pregnant women [5,6,12], are ignored in this regard. Religious fasting is one of the categories of dietary or food taboos, which may affect the dietary intake and nutritional status of lactating mothers, and these may lead to undernourished breastfed children. The main difference between religious fasting and the ordinary type of food taboo is its momentary nature, in which abstention from eating animal source foods and/or from eating certain foods is done for fixed periods of time [19]. According to previous studies, Ramadan fasting affected nutritional status, dietary nutrient intake, birth outcome, breast milk composition, and health status of women in reproductive age [20–28].

In Ethiopia, about half (44%) of the whole population are Ethiopian Orthodox Christians [9]. Religious fasting from any animal source foods and abstaining from any foods and water for some hours daily is mandatory. However, if it is practiced, it affects over 200 days annually [29].

Apart from this, children less than seven years old, soldiers, severely ill or weak people, pregnant, and lactating mothers are permitted to eat both animal source foods and other foods including water, without abstention during the religious fasting periods or days [19,29,30]. Nonetheless, information is lacking on the effect of religious fasting on the dietary and nutritional status of women in reproductive age. Therefore, the purpose of this study was to explore the dietary pattern and nutritional status of lactating women during Ethiopian Orthodox Lent fasting and non-fasting periods, and to identify potential predictors associated with maternal underweight in rural Tigray, Northern Ethiopia.

2.2. Materials and Methods

2.2.1. Study Area, Design, Participants, and Sampling

The study was conducted in the Genta Afeshum woreda of rural Tigray, Northern Ethiopia. The woreda covers an area of 1636 km^2 with a total population of 99,112, and almost all people (99%) are Orthodox Christians. The woreda reside at an altitude between 2045 and 3314 masl. The woreda is classified as a hotspot for food insecurity [31–33]. In the woreda, drought, hail storms, and livestock diseases are the major disaster risks; followed by human diseases, crop diseases, pests, and flooding. Additionally, deforestation, water pollution, and soil erosion are the major environmental problems; whereas, high dependency syndrome, poor economic conditions, land shortage, severe shortage of drinking water, and poor saving are among the major vulnerability factors at the household level [34].

The study had a community-based longitudinal survey design, to assess the nutritional status and dietary pattern of lactating mothers. The data was collected during the Ethiopian Orthodox lent fasting period (Fasting of Jesus Christ, 15 February 2017 to 15 April 2017) and non-fasting periods (1 May 2017 to 30 May 2017). The sample size was calculated based on the prevalence of underweight in lactating mothers in the Tigray region, using the formula for estimating single population proportion and considering a 95% of confidence interval for true prevalence, and a relative precision (d) of 5%. In lactating mothers, the prevalence of underweight (BMI < 18.5 kg/m^2) was 25% elsewhere in Tigray [5]. The total number of lactating mothers was estimated to be 3369, which was less than 10,000; therefore, the finite source population size correction formula was used. Additionally, 10% was considered as non-responses and dropout rates. Moreover, a 1.5 design effect was used on the final calculated sample size, and the final total sample size was 575.

Multi-stage systematic random sampling was applied to obtain representative samples for the study. At first, Genta Afeshum was randomly selected out of the three GIZ Ethiopia, Nutrition Sensitive Agriculture (NSA) project woreda's in Tigray region. Out of twenty rural kebeles in the Genta Afeshum woreda, seven were randomly selected. Then, the list of households which had lactating mothers with children aged between 6 to 23 months old, who fulfilled the inclusion criteria, was prepared for the seven kebeles (lowest local administrative unit) by health extension workers at the nearby health posts. Subsequently, the samples were chosen using systematic random sampling techniques.

2.2.2. Data Collection

Ten trained and well experienced data collectors who were fluent in Tigrigna, Amharic, and English languages were recruited. Additionally, before conducting the main survey, the questionnaire was translated to Tigrighna by a professional translator and verified by data collectors. Then the translated questionnaire was pre-tested for its appropriateness, by administering it to lactating mothers around Mekele, and corrections were made. Structured and semi-structured questionnaires were prepared to collect information on socio-demographic and economic characteristics, maternal and child characteristics, water, sanitation and hygiene (WASH), feeding practices, and household food security indicators [35].

Before conducting the study, the whole study protocol was ethically approved by the Institutional Review Board of the College of Health Sciences at Hawassa University and the Tigray Region Health Bureau in Ethiopia; and the ethical review committee of Landesärztekammer Baden-Württemberg, Germany. Permissions from Genta Afeshum Woreda Health Office were also obtained. After the purpose of the study was explained to the study participants, agreement to participate in the study was documented by signing the informed consent. Each participant was also told that the collected information was confidential, and whenever she wanted to discontinue, withdrawal from the study was possible.

2.2.3. Minimum Women Diet Diversity Score

The minimum-diet diversity score (MDD-W) was obtained by (a) collecting two 24-h dietary recalls; (b) categorizing as consumed or not consumed of the food group, considering the minimum amount (15 g) of any food items or the sum of food items eaten under a given food group and giving a score of 1 if consumed, otherwise 0 if not; (c) calculating the diet diversity score for each two days using 10 food groups, as the summation of consumed food groups or scored 1 for each day separately; and (d) taking the average diet diversity score of the two days, as an individual MDD-W score. The 10 food groups used for calculating MDD-W score were grains, white roots and tubers, and plantains; pulses (beans, peas, and lentils); nuts and seeds;

dairy; meat, poultry, and fish; eggs; dark green leafy vegetables; other vitamin A-rich fruits and vegetables; other vegetables; and other fruits [36].

2.2.4. Household Food Insecurity Information

Household food insecurity data was collected using the household food insecurity access scale (HFIAS). It is the measure of the degree of food insecurity (access) in the household in the past 4 weeks (30 days). The questionnaire encompassed nine questions, which assess the occurrence of food insecurity in increasing level. Under each of the nine questions, frequency of occurrence questions were a follow up to determine how often the condition (1 = rarely, 2 = sometimes, 3 = often) occurred.

The Household Food Insecurity Access Prevalence (HFIAP) status indicator, was used to determine prevalence of food insecurity to report household food insecurity. Using the HFIAP indicators four categories, the households were categorized into four levels of household food insecurity (access). These were food secure, mild, moderately, and severely food insecure. After creating these four categories, the HFIAP was calculated as the number of households with a given food insecurity category divided by the total number of households with household food insecure access category, multiplied by 100 [35].

2.2.5. Wealth Index

Principal component analysis (PCA) was carried out to compute the wealth index. To achieve this, 17 variables: transport animals (horse/donkey/mule), goat and/or sheep, household owns kerosene or lamp, owns bed, chair, table, radio, electric-mitad, bicycle, mobile phone, non-mobile phone, animal drawn cart, motor bicycle, TV, electricity, windows and separate room for animal, which could indicate the living standard of the surveyed area were included in the analysis. The first factor that explained most of the variation (86.3%) was used to group study households. Finally, the wealth tertile was performed and categorized as higher, medium, and lower [37].

2.2.6. Anthropometry

Weighing body mass of the mothers was conducted using a portable digital scale (Seca 770, Hanover, Germany), working with a powered battery and measured to the nearest 0.1 kg. For height measurement, a dissembling plastic height measuring board with a sliding head bar was used and measured to the nearest 0.1 cm. During weight and height measurements, the mothers were advised to remove their jackets until they had light clothes to minimize the weight due to clothes.

The measurements (height and weight) were carried out using standardized equipment and procedures in duplicate and the average values were used. Additionally, the BMI of the mothers was calculated as the weight of the mothers in kilograms divided by the square of their height in meters. The BMI values of mothers were classified in three categories as underweight, normal, and overweight (<18.5, 18.5–24.99 and 25 kg/m^2), respectively [38].

2.2.7. Data Management and Analysis

Before submitting the data, variable coding was conducted in SPSS version 20. Following this, the data was entered, cleaned, and analyzed. First, frequency and crosstab were conducted to determine completeness of data and to present the results in descriptive statistics (frequency and percent). Association between outcome and potential explanatory variables, was assessed using bivariate analysis with a confidence level of 95% to declare the statistical significance. Out of all the independent variables entered in bivariate logistic regression, seventy variables with p-values of less than 0.25 were entered for multivariable logistic regression to identify predictor variables for maternal underweight (BMI < 18.5 kg/m^2). p-value < 0.05 was used to declare the variables as predictors for the outcome variable. Hosmer and Lemeshow test and C-statistics (AUC) were conducted to assess fitness of the final model. Meanwhile, multi-collinearity was checked using the variance inflation factor (VIF) and standard error with <10 and <2 as a cutoff point, respectively. Maternal nutritional status was defined as underweight (BMI < 18.5 kg/m^2) and normal if BMI =>18.5 kg/m^2, since the interest ofthis study was being underweight for logistic regression. Normality of continuous data was checked using the Kolmogorov-Smirnov test. Non-normally distributed data was analyzed using the Wilcoxon signed-rank test; whereas the dichotomous data was analyzed using McNemar's test to detect a difference between fasting and non-fasting periods, of fasting and non-fasting mothers for their dietary pattern, separately.

2.3. Results

A total of 572 lactating mothers who were inhabitants of Genta Afeshum district of rural Tigray, Northern Ethiopia participated during the 1st round of data collection (Ethiopian Orthodox lent fasting) period, with a response rate of 99.5%. Out of those participants in the 1st survey, 522 mothers were again involved during the non-fasting period, with a response rate of 90.8%. The lost for follow-up was due to age (>23 months) of breastfeeding child, migration to other areas, and absence during the re-visit at the 2nd round survey period.

In this study, all mothers were from the Tigray ethnic group (100%) and almost all were Ethiopian Orthodox Christians (99.7%). Majority of mothers were married (84.8%); whereas, the rest were single, widowed, and divorced mothers. More than sixty percent of mothers were thirty years old and above in the study. However, about eight out of ten mothers were married before the age of 21 years. The proportion of mothers who were illiterate and housewives were 35.1% and 79.2%, respectively. Nearly sixty percent of mothers had children of one year and above. Majority of the households were food insecure (71%), male-headed (80%), and taking aid (food, cash, in kind) (89%) before the survey period, from local government or humanitarian organizations. Likewise, 61.4% and 75% of households had family members of more than five and resided in an area more than 15 km away from the largest market in the district, respectively (Table 2.1).

Table 2.1 Socio-demographic and economic characteristics of the study participants (n = 572) in rural Tigray, Northern Ethiopia (February–June, 2017).

Characteristics (n = 572)		**Number**	**Percent**
Ethnicity of mother	Tigray	572	100
Religion of mother	Orthodox	570	99.7
	Other	2	0.3
Current maternal age (years)	>30	227	39.7
	≤30	345	60.3
Mother age at marriage (years)	>20	116	20.3
	≤20	456	79.7
Mother age at giving 1st birth (years)	>20	279	48.8
	≤20	293	51.2
Family size	≤5	221	38.6
	>5	351	61.4
Household previous aid experience	No	64	11.2
	Yes	508	88.8
Household main income decision maker	Husband	129	22.6
	Jointly husband and wife	352	61.5
	Wife	74	12.9
	Grand father	17	3.0
Age of child (months)	≤12	241	42.1
	13–18	200	35.0
	>18	131	22.9
Mother previous credit experience from local	No	438	76.6

institutes	Yes	134	23.4
Distance from woreda market (km)	≤15	143	25.0
	>15	429	75.0
Marital status	Married	485	84.8
	Others	87	15.2
Mother education	Illiterate	201	35.1
	Literate	371	64.9
Mother occupation	Housewives	453	79.2
	Farmer	81	14.2
	Daily laborer	15	2.6
	Business owner	15	2.6
	Employee	8	1.4
Household head	Father	458	80.1
	Mother	114	19.9
Household food security status	Food secured	166	29.0
	Mildly food insecure	181	31.6
	Moderately food insecure	213	37.3
	Severely food insecure	12	2.1
	Higher	149	26.1
Wealth tertile	Medium	237	41.4
	Lower	186	32.5
Household chicken owning	No	247	43.2
	Yes	325	56.8

As shown in Table 2.2, 28% and 31% of mothers were fasting during the pregnancy and lactation period of the indexed child, respectively. Beside this, 65% of mothers did not change their food intake during their lactation period. Very small proportion of mothers (13.8%), had illness within four weeks preceding the fasting period. Most of the mothers (91%), used antenatal care (ANC) services four times or more during pregnancy of the indexed child. However, mothers who received post-natal care (PNC) services after delivery were 43%. (Table 2.2).

Mothers less than or equal to thirty years of age, were about 1.7 times more likely to be underweight than those above thirty years (Adjusted Odds Ratio (AOR) = 1.73). Conversely, mothers who had children between 13 and 18 months of age had two times higher odds of being underweight, compared to those mothers who had children between six to twelve months of age

(AOR = 2.01). Households having no access to improved water and not owning chickens, were more likely to have underweight mothers compared to their counterparts (AOR = 1.57, 1.73, respectively). However, family size, marital status, family planning method used, distance from woreda market, number of ANC visits, PNC attendance, toilet presence, and wealth index had no association with maternal underweight (Table 2.3).

Table 2.2 Maternal health and feeding practices (n = 572) in rural Tigray, Northern Ethiopia (February–June 2017).

Characteristics (n = 572)		Numbers	Percent
Fasting during lactation	No fasting	394	68.9
	Fasting	178	31.1
Fasting during pregnancy	No fasting	414	72.4
	Fasting	158	27.6
Change of food intake	No	374	65.4
	Yes	198	34.6
Number of visits in antenatal care	≥4	518	90.6
	<4	54	9.4
Attendance of postnatal care service after delivery	No	329	57.5
	Yes	243	42.5
Household water source	Improved	379	66.3
	Non-improved	193	33.7
Household toilet presence	No	112	19.6
	Yes	460	80.4
Household garbage pit presence	No	74	12.9
	Yes	498	87.1
Family planning methods	No	274	47.9
	Yes	298	52.1
Sickness last 4 weeks	No	493	86.2
	Yes	79	13.8

The odds of being underweight for mothers fasting during their pregnancy and lactation period of the indexed child, were 1.7 and 2.8 times higher than those who were not fasting in both periods (AOR = 1.75, 2.82), respectively. Additionally, mothers who had sickness within four weeks preceding the fasting period had 3.6 times higher odds of being underweight, compared to those who were healthy (AOR = 3.62). Similarly, households whose decision makers were grandfathers and had received aid were 6.0 and 2.9 times more likely to have underweight mothers, compared to households with husbands as decision makers and those which did not receive aid (AOR = 6.02, 2.86, respectively).

Table 2.3 Association of some socio-demographic, health, and feeding practice variables with maternal underweight (BMI) during Ethiopian Orthodox Lent fasting period in Rural Tigray, Northern Ethiopia (n = 572).

Variables	Underweight		COR (95% CI)	AOR (95% CI)
	No	Yes		
	Number (%)	Number (%)		
Mother age				
>30	158 (69.6)	69 (30.4)	1	1
≤30	222 (64.3)	123 (35.7)	1.27 (1.11, 2.71)	1.73 (1.11, 2.71)*
Mother fasting status during pregnancy period of indexed child				
No	301 (72.7)	113 (27.3)	1	1
Yes	79 (50.0)	79 (50.0)	2.66 (1.82, 3.89)*	1.75 (1.11, 2.75) *
Mother fasting status during lactation period of indexed child				
No	292 (74.1)	102 (25.9)	1	1
Yes	88 (49.4)	90 (50.6)	2.93 (2.02, 4.24)*	2.82 (1.80, 4.42)*
Family size				
≤5	159 (71.9)	62 (28.1)	1	1
>5	221 (63.0)	130 (37.0)	1.51 (1.05, 2.17)	1.42 (0.87, 2.32)
Decision maker on main household income				
Husband	83 (64.3)	46 (35.7)	1	1
Jointly husband and wife	246 (69.90)	106 (30.1)	0.78 (0.51, 1.19)	0.65 (0.39, 1.09)
Wife	46 (62.2)	28 (37.8)	1.10 (0.61, 1.98)	0.94 (0.35, 2.47)
Grand father	5 (29.4)	12 (70.6)	4.33 (1.44,13.06)*	6.02 (1.47, 24.80)*
Marital status				
Married	330 (68.0)	155 (32.0)	1	1
Others	50 (57.5)	37 (42.5)	1.58 (0.99, 2.51)	1.28 (0.52, 3.17)
Age of indexed child				
≤12 months	171 (71.0)	70 (29.0)	1	1
13–18	120 (60.0)	80 (40.0)	1.63 (1.10, 2.42)*	2.01 (1.27, 3.18)*
>18	89 (67.9)	42 (32.1)	1.15 (0.73, 1.83)	1.14 (0.67, 1.96)
Household previous experience to aid				

No	53 (82.8)	11 [17.2]	1	1
Yes	327 (64.4)	181 [35.6]	2.67 (1.36, 5.23)*	2.86 (1.32, 6.20)*
Family planning use status				
Yes	205 (68.8)	93 (31.2)	1	1
No	175 (63.9)	99 (36.1)	1.25 (0.88, 1.76)	1.12 (0.74, 1.69)
Distance from woreda market				
≤15	101 (70.6)	42 (29.4)	1	1
>15	279 (65.0)	150 (35.09	1.29 (0.86, 1.95)	1.26 (0.72, 2.21)
ANC number visited during the pregnancy period of indexed child				
≥4	349 (67.4)	169 (32.6)	1	1
<4	31 (57.4)	23 (42.6)	1.53 (0.87, 2.71)	0.97 (0.49, 1.94)
Mother PNC				
Yes	169 (69.5)	74 (30.5)	1	1
No	211 (64.1)	118 (35.9)	1.28 (.90, 1.82)	1.01 (0.66, 1.55)
Household consumption water source				
Improved	263 (69.4)	116 (30.6)	1	1
Non-improved	117 (60.6)	76 (39.4)	1.47 (1.03, 2.12)*	1.57 (1.02, 2.43)*
Toilet presence in the household				
Yes	311 (67.6)	149 (32.4)	1	1
No	69 (61.6)	43 (38.4)	1.30 (0.85, 1.99)	1.48 (0.90, 2.43)
Household chicken owning status				
Yes	229 (70.5)	96 [29.5]	1	1
No	151 (61.1)	96 [38.9]	1.52 (1.07, 2.15)*	1.73 (1.15, 2.61)*
Mother sickness last one month preceding the survey				
No	350 (71.0)	143 (29.0)	1	1
Yes	30 (38.0)	49 (62.0)	3.99 (2.44, 6.55) *	3.62 (2.00, 6.54) *
Wealth status tertile				
Higher	134 (72.0)	52 (28.0)	1	1
Medium	153 (64.6)	84 (35.4)	0.64 (0.41, 1.02)	0.98 (0.53, 1.83)
Lower	93 (62.4)	56 (37.6)	0.91 (0.60, 1.40)	0.86 (0.52,1.41)

COR = Crude Odds Ratio; AOR = Adjusted Odds Ratio; CI = confidence interval; Hosmer and Lemeshow test showed p = 0.197; C-statistic: Area under the Curve (AUC) = 0.766; 95% CI (0.724–0.809); *=significantly associated at p<0.05.

Variables included in the adjusted model logistic regression: Mother age, Mother fasting status during pregnancy period of indexed child, Mother fasting status during lactation period of indexed child, Family size, Decision maker on main household income, Marital status, Age of indexed child, Household previous experience to aid, Family planning use status, Distance from woreda market, ANC number visits during the pregnancy period of indexed child, Mother PNC, Household consumption water source, Toilet presence in the household, Household chicken owning status, Mother sickness last one month preceding the survey, and Wealth status tertile.

A small fraction of mothers (1.4%) had height < 145 cm, indicating stunting. Nearly one-third of mothers had body weight < 45 kg (32.5%) and BMI < 18.5 kg/m^2 (33.6%), in the study population. However, the prevalence was higher in fasting mothers than non-fasting mothers, both in the fasting and non-fasting period. However, the prevalence of overweight (BMI 25 kg/m^2) was lower in fasting mothers than non-fasting in both periods, as shown in Table 2.4.

Table 2.4 Food consumption and anthropometric status of lactating mothers during Ethiopian Orthodox lent fasting and non-fasting periods at rural Tigray, Northern Ethiopia.

Variables		**Lent Fasting Period (n = 572)**			**Non-Fasting Period (n = 522)**		
		Non-Fasting Mothers	**Fasting Mothers**	**Total**	**Non-Fasting Mothers**	**Fasting Mothers**	**Total**
		n (%)	**n (%)**	**n (%)**	**n (%)**	**n (%)**	**n (%)**
Height (cm)	<145	7 (1.8)	1 (0.6)	8 (1.4)			
	≥145	387 (98.2)	177 (99.4)	564 (98.6)			
Weight (kg)	≤45 kg	106 (26.9)	80 (44.9)	186 (32.5)	97 (26.8)	71 (44.4)	168 (32.2)
	>45 kg	288 (73.1)	98 (55.1)	386 (67.5)	265 (73.2)	89 (55.6)	354 (67.8)
BMI (kg/ m^2)	<18.5	102 (25.9)	90 (50.6)	192 (33.6)	90 (24.9)	81 (50.6)	171 (32.8)
	18.5–24.99	277 (70.3)	86 (48.3)	363 (63.4)	259 (71.5)	77 (48.1)	336 (64.3)
	≥25	15 (3.8)	2 (1.1)	17 (3.0)	13 (3.6)	2 (1.2)	15 (2.9)
Diet diversity score (MDD-W)	<3	199 (50.5)	101 (56.7)	300 (52.5)	163 (45.0)	73 (45.6)	236 (45.2)
	3	161 (40.9)	65 (36.5)	226 (39.5)	149 (41.2)	65 (40.6)	214 (41.0)
	>3	34 (8.6)	12 (6.7)	46 (8.0)	50 (13.8)	22 (13.8)	72 (13.8)
Number of meals	<3	119 (30.2)	64 (36.0)	183 (32.0)	29 (8.0)	15 (9.4)	44 (8.4)
	3	226 (57.4)	92 (51.7)	318 (55.6)	299 (82.6)	131 (81.9)	430 (82.4)
	>3	49 (12.4)	22 (12.4)	71 (12.4)	34 (9.4)	14 (8.8)	48 (9.2)
Number of cups of coffee	<2	208 (52.8)	105 (59.0)	313 (54.7)	215 (59.4)	94 (58.8)	309 (59.2)
	≥2	186 (47.2)	73 (41.0)	259 (45.3)	147 (40.6)	66 (41.2)	213 (40.8)

Grain consumption	394 (100.0)	178 (100.0)	572 (100.0)	362 (100.0)	160 (100.0)	522 (100.0)
Pulse consumption	383 (97.2)	170 (95.5)	553 (96.7)	355 (98.1)	157 (98.1)	512 (98.1)
Nuts and seeds consumption	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Dairy products consumption	8 (2.0)	0 (0.0)	8 (1.4)	23 (6.4)	9 (5.6)	32 (6.1)
Meat, poultry and fish consumption	2 (0.5)	0 (0.0)	2 (0.3)	60 (16.6)	19 (11.9)	79 (15.1)
Eggs consumption	4 (1.0)	2 (1.1)	6 (1.0)	19 (5.2)	12 (7.5)	31 (5.9)
Dark green leafy vegetables consumption	45 (11.4)	18 (10.1)	63 (11.0)	10 (2.8)	9 (5.6)	19 (3.6)
Vitamin A-rich fruits and vegetables consumption	4 (1.0)	1 (0.6)	5 (0.9)	0 (0.0)	1 (0.6)	1 (0.2)
Other vegetables consumption	294 (74.6)	130 (73.0)	424 (74.1)	265 (73.2)	116 (72.5)	381 (73.0)
Other fruits consumption	0 (0.0)	2 (1.1)	2 (0.3)	0 (0.0)	0 (0.0)	0 (0.0)

Our findings demonstrated that the number of mothers who were in the fasting sub-group and had a diet diversity score (MDD-W) less than three, were slightly more in the fasting (56.7%) than non-fasting period (45.6%). However, the proportion of fasting and non-fasting mothers who scored a diet diversity greater than three, increased from the fasting period (6.7% and 8.6%, respectively) to non-fasting period (13.8%). Fasting mothers reduced consumption of coffee in the fasting period (41%), whereas non-fasting mothers (47.2%) did not. In both study periods, all mothers consumed grains, but there was no consumption of nuts and seeds. Almost all mothers ate pulses in fasting (96.7%) and non-fasting (98.1%) periods. Conversely, except two fasting mothers in fasting period, there was no consumption of other fruit groups in both periods. Furthermore, mothers who consumed vitamin A-rich fruits and vegetables preceding the survey days in both periods were less than 1%. The overall consumption of dark green, leafy vegetables was lower in the non-fasting (3.6%) than fasting period (11%). The consumption of other vegetable groups was almost the same during non-fasting (73%) and fasting (74.1%) periods. Dairy products; meat, poultry and fish; and eggs food groups were consumed by a very low number of both fasting (0%, 0% and 1.1%) and non-fasting mothers (1.4%, 0.3% and 1%) during the fasting period, respectively. However, consumption of the three ASFs significantly increased in both fasting and non-fasting mothers, in the non-fasting period compared to fasting period, as shown in Table 2.4. According to McNemar's test, there was no significant difference on the proportion of fasting mothers who consumed pulses ($p = 0.289$), dark green leafy vegetables ($p = 0.078$), vitamin A-rich fruits and vegetables ($p = 1.000$), and other vegetables groups ($p = 1.000$), between fasting and non-fasting periods. However, the proportions of fasting and non-fasting mothers who consumed eggs, were significantly higher in non-fasting than fasting periods ($p = 0.006$, $p = 0.003$, respectively). Similarly, the consumption of pulses and other vegetable groups by non-fasting mothers were not significantly different ($p = 0.332$, $p = 0.716$, respectively), between fasting and non-fasting periods. However, the number of non-fasting mothers who consumed dairy; meat, poultry and fish products; eggs; and dark green leafy vegetables were significantly different ($p = 0.002$, $p = 0.001$, $p = 0.003$ and $p = 0.001$, respectively), between fasting and non-fasting periods (Table 2.5).

Using the Wilcoxon signed-rank test, the median BMI, body weight of fasting mothers, and number of cups of coffee consumed were not significantly different between fasting and non-fasting periods. Similarly, the median BMI and body weight of non-fasting mothers were not statistically different between the two periods (Tables 2.6 and 2.7). However, in both fasting and non-fasting mothers, the number of meals eaten ($p = 0.001$), MDD-W ($p = 0.037$ and $p = 0.014$), and ASFs consumption scores ($p = 0.001$) were significantly increased in the non-fasting than fasting periods, respectively. However, the number of cups of coffee consumed by non-fasting mothers was significantly ($p = 0.009$) higher in fasting period than in the non-fasting period (Tables 2.6 and 2.7).

Table 2.5 Food consumption status of fasting and non-fasting mothers, during Ethiopian Orthodox lent fasting and non-fasting periods in rural Tigray, Northern Ethiopia.

Parameters	**Fasting Mothers (a, n = 160)**			**Non-Fasting Mothers (b, n = 362)**		
	Lent Fasting Period	**Non-Fasting Period**	**Significance**	**Lent Fasting Period**	**Non-Fasting Period**	**Significance**
	n (%)	**n (%)**	***p*-value**	**n (%)**	**n (%)**	***p*-value**
Grain consumption	160 (100.0)	160 (100.0)	NA	362 (100.0)	362 (100.0)	NA
Pulse consumption	153 (95.6)	157 (98.1)	0.289	351 (97.0)	356 (98.3)	0.332
Nuts and seeds consumption	0 (0.0)	0 (0.0)	NA	0 (0.0)	0 (0.0)	NA
Dairy products consumption	0 (0.0)	9 (5.1)	NA	7 (1.9)	23 (6.4)	0.002 *
Meat, poultry and fish consumption	0 (0.0)	19 (11.9)	NA	2 (0.6)	60 (16.6)	≤0.001 *
Eggs consumption	2 (1.2)	12 (7.5)	0.006 *	4 (1.1)	19 (5.2)	0.003 *
Dark green leafy vegetables consumption	18 (11.2)	9 (5.6)	0.078	41 (11.3)	10 (2.8)	≤0.001 *
vitamin A-rich fruits and vegetables consumption	1 (0.6)	1 (0.6)	1.000	4 (1.1)	0 (0.0)	NA
Other vegetables consumption	116 (72.5)	116 (72.5)	1.000	270 (74.6)	265 (73.2)	0.716
Other fruits consumption	1 (0.6)	0 (0.0)	NA	0 (0.0)	0 (0.0)	NA

Data analysis using McNemar's test, significant level at $p < 0.05$, a < b, NA-the data was not appropriate for analysis; *=significantly associated at $p<0.05$.

Table 2.6 Comparison of fasting mothers' food consumption and anthropometric status between Orthodox lent fasting and non-fasting periods in rural Tigray, Northern Ethiopia.

Variables (N = 160)	Data Collection Period						
	Lent Fasting (a)			Non-Fasting (b)			
	Mean (SD)	Median (IQR)	Range (Min, Max)	Mean (SD)	Median (IQR)	Range (Max, Min)	Sign
Weight (kg)	46.18 (5.55)	45.55 (42.23, 49.48)a	(35.40, 65.60)	45.98 (5.49)	45.65 (42.23, 48.90)a	35.30, 65.40	0.054
BMI (kg/m^2)	18.86 (2.14)	18.47 (17.55, 20.05)a	(14.79, 27.99)	18.79 (2.18)	18.48 (17.49, 20.0)a	14.75, 28.21	0.051
Diet Diversity Score (MDD-W)	2.57 (0.54)	2.50 (2.0, 3.0)a	(1.00, 4.0)	2.69 (0.58)	3.0 (2.0, 3.0)b	1.50, 4.0	0.037
ASFs Score	0.01 (0.06)	0 (0, 0)a	(0, 0.50)	0.13 (0.27)	0 (0, 0)b	0, 1.0	≤0.001
Number of meals	2.79 (0.49)	3.0 (2.5, 3.0)a	(1.50, 4.0)	3 (0.29)	3.0 (3.0, 3.0)b	2.0, 4.50	≤0.001
Number of cup of coffee	2.64 (3.4)	1.5 (0, 3.0)a	(0, 12.0)	1.74 (1.67)	1.5 (0, 3.0)a	0, 7.50	0.058

Data analysis using Wilcoxon Signed Ranks Test significant level at $p < 0.05$, a < b.

Table 2.7 Comparison of non-fasting mothers' food consumption and anthropometric status between Orthodox Lent fasting and non-fasting periods in rural Tigray, Northern Ethiopia.

Variables (N = 362)	Data Collection Period						
	Lent Fasting (a)			Non-Fasting (b)			
	Mean (SD)	Median (IQR)	Range (Min, Max)	Mean (SD)	Median (IQR)	Range (Max, Min)	Sign
Weight (kg)	49.30 (6.41)	48.50 (45.10, 53.10)a	35.50, 72.00	49.20 (6.61)	48.50 (44.60, 53.13)a	35.70, 74.00	0.092
BMI (kg/m^2)	20.08 (2.36)	19.68 (18.53, 21.34)a	15.87, 29.91	20.04 (2.43)	19.64 (18.50, 21.48)a	15.57, 29.79	0.086
Diet Diversity Score (MDD-W)	2.63 (0.53)	2.50 (2.00, 3.00)a	1.00, 4.00	2.73 (0.55)	3.00 (2.00, 3.00)b	1.50, 4.50	0.014
ASFs Score	0.02 (0.12)	0.00 (0.00, 0.00)a	0.00, 1.00	0.16 (0.31)	0.00 (0.00, 0.00)b	0.00, 1.50	≤0.001
Number of meals	2.84 (0.50)	3.00 (2.50, 3.00)a	1.00, 4.50	3.01 (0.27)	3.00 (3.00, 3.00)b	2.00, 4.50	≤0.001
Number of cup of coffee	2.12 (1.96)	1.5 (0.00, 3.00)b	0.00, 9.00	1.76 (1.57)	1.5 (0.00, 3.00)a	0.00, 6.00	0.009

Data analysis using Wilcoxon Signed Ranks Test significant level at $p < 0.05$, a < b.

4. Discussion

This study assessed whether nutritional status and dietary pattern of lactating mothers were different between Ethiopian Orthodox lent fasting and non-fasting periods. It also determined factors associated with maternal underweight in rural Tigray, Northern Ethiopia.

4.1. Nutritional Status of Lactating Mothers

Adult stature is the collective outcome of the interaction between environment and inheritances, over the critical growing period of a person [39]. Prior evidence has demonstrated that short maternal height was associated with increased offspring mortality, underweight, and stunting in infancy, childhood, and later in an adult age [39,40]. In our study, prevalence of maternal stunting was 1.4%, which was less than previous findings in Ethiopia [5,9,10,41]. Shorter women are believed to have reduced protein and energy stores, smaller size of their reproductive organs, and smaller pelvis diameter. This may limit fetal development in the uterus, increases risk for mother and child complication during delivery, and later infant growth through reduced breast milk quantity and quality, resulting in stunted children. Thus, appropriate feeding behavior is important for pregnant women health, and later for bearing healthier and well grown new born babies. This finding suggests that health extension agents working in the rural communities should advise mothers on appropriate feeding behavior during the pregnancy period.

The overall prevalence of maternal underweight in this study was between 32.6 and 33.6%. The prevalence was lower than previous findings in Tigray region (34–55%), and Dedo and Seqa-Chekorsa districts (41%), in South-west Ethiopia [9–12]. Conversely, the prevalence was higher than in other studies in the Tigray and Oromia regions of Ethiopia [5,41–44]. The latter could be related to climate phenomenon ‘El Nino’, which caused the strongest famine in Ethiopia, where the impact seriously affected Tigray region. It could also be related to differences in feeding practices, study population, and period [45].

Shockingly, prevalence of underweight was 51% in fasting mothers compared with non-fasting mothers (25%). The result was consistent with studies conducted on lactating mothers living in the midland agro-ecology of Tigray region, which was 57% [12]. Similarly, the BMI was significantly lower among fasting adults than non-fasting adults in Greek Orthodox Christians [28]. This could be related to the almost 317 kcal difference between fasting and non-fasting adults, in end-holy days of fasting periods [46].

In the present study, prevalence of overweight was between 1.1–3.8%, which was relatively comparable with the Ethiopian Demographic and Health Survey (EDHS) 2011 report (2.9%) in Tigray, and elsewhere (1.3–1.8%) in the region [5,24,38], but lower than the EDHS (2016) report at national level (6%) and Tigray region (4.9%). In urban women, it was reported (6.2–25.3%) in Ethiopia, Bengal district in India (5.4%), and Nepal (6.3–24.8%) [44,47–52]. This might be because we attributed this finding to rural people [10], where most could engage in heavy physical activities and walking over long distances to access services due to the mountainous topography [53,54].

Mothers thirty years of age and younger were 1.7 times more likely to be underweight than those above thirty. That conforms with other studies conducted in Ethiopia and Nepal, resulting in higher prevalence of underweight in younger women [10,47]. In the current study, more than 27% of mothers fasted during their pregnancy period, and these mothers had 1.7 times more odds to be underweight than not fasting during the same period. In a previous study, more than one-third of mothers were fasting during their pregnancy period in Oromia region, Ethiopia [15]. Similarly, those mothers fasting during lactation period were 2.9 times more exposed to underweight, than those who did not practice. Mothers who had children between the age of 13 and 18 months, were twice more likely to be underweight compared to those who had a child aged 6–12 months. Similar result was observed in a study conducted by Haileslassie and his colleagues in Northern Ethiopia [5]. This might be due to increased nutritional requirements of the growing child, effort for child care in connection with food intake by the mother that is not increased or even decreased.

Disease is one of the immediate causes of maternal and child undernutrition [1]. Mothers who had any illness in the last four weeks preceding the survey were 3.6 times more frequently underweight than healthy mothers. In a study conducted in the Limu area of Southern Ethiopia, maternal sickness was positively associated with maternal underweight [55]. This could be related to decreased food intake and absorption, alteration of metabolism, and increment in nutritional requirements. Marital status of lactating mothers was not significantly associated with maternal underweight. Prior evidence has also demonstrated that marital status was not associated with Ethiopian women [56]. Otherwise, birth spacing has important implications for the health and nutritional status of mothers and their children [57]. In our study, family planning use was not associated with maternal underweight, which is inconsistent with the study conducted in the Tena district of Oromia region, Ethiopia. In the latter, the prevalence of family planning utilization was higher (65%) than our finding, which was 52% [58].

Good care during pregnancy is important for the health of the mother and development of the unborn baby. The findings of this study indicated that a major proportion (91%) of mothers had at least four ANC services during their pregnancy period, and were not significantly associated with maternal underweight. This result was equal with the regional coverage of Tigray (91%), but higher than the national prevalence (62%) [10]. The postnatal period is a critical phase in the lives of a mother and the newborn baby. In this period, major changes occur, but it is the most neglected time for the provision of quality services. As a result, the rates of provision of skilled care are lower after childbirth when compared to rates before and during childbirth [59]. In this study, prevalence of PNC coverage was 42.5%, which is comparable with previous findings in Tigray region (45.4%); however, PNC attendance was not significantly associated with maternal undernutrition. Household size was not significantly associated with maternal underweight in the study. This coincides with studies in Southern Ethiopia and Tigray region [5,41,55]. However, it was inconsistent with one study conducted in Nekemte town, Oromia region in Ethiopia [44]. The difference might be a higher proportion of lactating mothers who lived in rural households with many family members, in our case. Grandfathers as a decision maker for the household were associated with maternal underweight. This could be related to sharing the household income to more family members or to the loss (death, departure) of the husband resulting in lower working capacity and income, or due to most lactating mothers in grandfather headed households being younger, which is associated with maternal underweight in our case. It has also been reported that mothers who had more children, decreases the resources allocated including food, resulting in underweight [60]. Access to safe drinking water, sanitation and hygiene (WASH) services is a fundamental element of healthy communities and has an important positive impact on child and maternal nutrition [61,62].

One-third of households included in this study, had non-improved water sources for household consumption. The odds of being underweight for mothers from non-improved water sources were 1.6 higher than those from households with improved water sources. This may be due to the fact of frequent illness related to water borne diseases and contamination. Accordingly, child undernutrition was associated with source of drinking water in Iraq and sub-Saharan Africa

[63,64]. In contrast, toilet presence in the household was not associated with maternal underweight. This might apply to the majority of households included in the study, one of the successes of the health extension program in Ethiopia. In our study, households not owning chickens were 1.8 times more likely to have underweight mothers, than those who owned chickens. Similarly, the proportion of mothers who ate more diversified foods were higher in households which owned chicken, than those from households not owning chicken. Prior research in Ethiopia, indicated that owning livestock in the household was associated with a higher diet diversity score [65]. Studies in three East African countries also evidenced that, in households owning livestock, the prevalence of child stunting was low [66]. Thus, promoting chicken husbandry may also improve the low consumption of animal source foods, and the diversity of food to be eaten at large. Among households involved in the study, more than a quarter (32.5%) were at the lowest wealth tertile. According to the EDHS report, a lower proportion of households (23%) was at the lowest wealth quantile [10]. Of thirty-four woreda's in Tigray region, thirty-one were food insecure, including our study district [33]. The results from the present study showed that more than two-thirds (71%) of households were food insecure. Comparably, the prevalence of food insecurity was 76% in East Bedawacho district of Southern Ethiopia [67]. However, the prevalence was lower than in a study conducted in two agro-climatic zones in Sidama, Southern Ethiopia, which was 82% [68].

4.2. Dietary Patterns of Lactating Mothers

According to the essential nutrition action (ENA), mothers are recommended to take at least two additional meals during their lactation period [69]. In the present study, nearly two-thirds of the mothers (65.4%) did not change the food intake during their lactation period. This result is lower than a study conducted in Samre district which reported (71%), but higher than findings in Raya area (59%) of Tigray region. This could be related to the interval in the study periods and study area [5,41].

Lactating mothers who ate more than three times a day were 9–12%. This result agreed with findings in the Tigray, Oromia, and Southern regions in Ethiopia [11,41]. One-third of lactating mothers ate less than three times on average of the two days preceding the survey during fasting period, which is lower than the expected three meals to have in a day of a normal adult in real context. Prior research in Samre district of Northern Ethiopia, showed that the proportion of lactating mothers who had less than three meals in the last 24-h preceding their survey was 27% [5], which is comparable with our findings. However, this prevalence reduced to 8.4% in the non-fasting period, which is comparable with the prevalence (7.5%) of pregnant women in Gambela town, Western Ethiopia [70]. Similarly, the number of meals eaten both by fasting and non-fasting mothers were significantly increased after two months of fasting period. The latter should be further studied for explanation.

Diet diversity is one important dimension of diet quality, and a proxy indicator for higher micronutrient adequacy [36]. Majority of mothers had a diet diversity score of three and less in the fasting period (92%) and non-fasting period (87%). This could indicate that dietary micronutrient inadequacy is high in the study population. The median diet diversity score for both sub-groups of fasting and non-fasting mothers, increased significantly in non-fasting period. This was associated with higher consumption of ASFs and a higher frequency of meals in our and related studies [65,71,72]. Thus, in the Ethiopian Orthodox fasting period, the feeding practice of lactating mothers is sub-optimal. This finding suggests that nutrition education, which will improve feeding practices should involve religious leaders in a sustainable manner. The number of mothers who had consumed more cups of coffee was higher in the fasting than non-fasting period, in the whole study population. Likewise, non-fasting mothers took significantly more coffee in the fasting period than non-fasting. However, consuming more coffee during the fasting period, where plant-based foods are the sole source of minerals, could reduce their bioavailability, leading to increased risk for micronutrient deficiencies, especially of iron, calcium, and zinc [73]. However, many fasting mothers consumed more cups of coffee in the non-fasting than fasting period. This could be referred to some Ethiopian Orthodox religion monarchist, who preached to followers not to consume coffee during fasting periods.

In this study, cereals, pulses, and other vegetables were the main food groups commonly consumed by lactating mothers. This result agrees with previous studies in Ethiopia [65,71,74]. These plant foods usually contain dietary components that compromise digestion and inhibit absorption of vital nutrients. For example, phytic acid chelates multivalent ions such as zinc, calcium, and iron; therefore, their bioavailability reduced [75]. This finding suggests that traditional processing techniques which can improve the bioavailability of minerals should be promoted in the community.

Dark green, leafy vegetables are important plant sources of micronutrients like iron, calcium, and vitamin A [76]. However, their consumption was very low in the non-fasting period, both in fasting (5.6%) and non-fasting (2.8%) mothers. However, the result was lower than that previously reported for Axum town (19%) in Northern Ethiopia. The discrepancy between these two findings could be related to better market access, which is less in this study due to the rural area. However, the number of non-fasting mothers who consumed dark green, leafy vegetables was significantly higher in the fasting period than non-fasting period. This could be related to a potential to choose and consume more diversified food, especially ASFs which were less consumed in fasting period. Furthermore, almost all lactating mothers did not consume nuts and seeds, fruits, and vitamin A rich fruits and vegetables food groups at all in both study periods, because of a lack of cultivation on local farms and unavailability in the market [77]. Thus, activities which can improve the dietary diversity including nuts and seeds, dark green leafy vegetables, and vitamin A and C rich fruits consumption, as well as meal frequency are inevitable. Moreover, the consumption of fruits which are rich in vitamin C should be taught to improve the mineral bioavailability of plant foods, which are the predominate source of most nutrients for a given community.

The proportion of lactating mothers who consumed ASFs was significantly lower in the fasting than non-fasting period. In Northern Ethiopia, particularly in rural Tigray, most strict Ethiopian Orthodox Christians abstain from eating animal source foods during the lent and other fasting periods or days, including Wednesday and Friday. During these fasting periods, the demand for cattle meat was observed to be low, resulting in closure of abattoirs or minimizing the service provided [78]. A previous study, reported that more than 85% of butcher houses were closed in Addis Ababa during Wednesday and Friday, which are Orthodox Christians fasting days of the week [79].

This study has much strength and some limitations. It is the first study in Ethiopia, which assessed the effect of religious fasting on maternal nutrition, particularly lactating mothers, who need more nutrients than pregnant women. Moreover, the study was done in an area, where almost all people were Ethiopian Orthodox Christians to minimize research bias. In addition, the study had a longitudinal nature, which considered a large sample size, and two 24-h dietary recall data for each study period. On top of these, this study also determined the differences in dietary and nutritional status during fasting and non-fasting periods, for both fasting and non-fasting mothers' sub-groups, separately. However, the study only considered the long Ethiopian

Orthodox lent fasting period out of the seven official fasting periods. This study did not measure micronutrient levels or bio-markers in the blood, to assess micronutrient deficiencies reflecting the consequences of qualitative malnutrition. Underweight only indicates energetic malnutrition, representing the tip of the iceberg.

5. Conclusions

It has been found that the prevalence of underweight among fasting, lactating mothers during Ethiopian Orthodox fasting periods is high and a serious public health problem in the district. The dietary pattern [diet diversity and number of meals eaten] of lactating mothers is sub-optimal, both in fasting and non-fasting periods. Cereals and pulses are the dominant food groups eaten in the district, known to have a high amount of anti-nutrients like phytic acid, which limit the bioavailability of minerals for absorption. Therefore, activities which will improve dietary diversity including nuts and seeds, dark green leafy vegetables, and vitamin A and C rich fruits consumption, as well as meal frequency are urgently needed. Additionally, consuming vitamin C rich fruits and use of traditional processing techniques, which can improve the bioavailability of minerals should be promoted. Furthermore, promoting chicken husbandry may also improve the low consumption of animal source foods. Though moderate intake of coffee is beneficial, consuming coffee closely to meals to be eaten will decrease the absorption of non-heme iron from plant source foods and should be discouraged. Thus, households with younger mothers and non-improved water sources should get priority in nutritional intervention. Generally, multi-sectoral nutrition intervention strategies should include religious institutions to reduce maternal malnutrition in Ethiopia. Otherwise, nutrition education activities will not lead to sustainable improvements.

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Chapter 3

Paper II

3. Feeding Practices and Undernutrition in 6–23-Month-Old Children of Orthodox Christian Mothers in Rural Tigray, Ethiopia: Longitudinal Study

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Feeding Practices and Undernutrition in 6–23-Month-Old Children of Orthodox Christian Mothers in Rural Tigray, Ethiopia: Longitudinal Study

Abstract

Fasting period and fasting status affect the feeding practices and nutritional status of Ethiopian Orthodox mothers. Even if children are exempted from fasting, some mothers do not prepare their food from animal sources as it could contaminate utensils for cooking family foods. Therefore, the objective of this study was to assess feeding practices and undernutrition in 6–23-months old children whose mothers are Ethiopian Orthodox religion followers during lent fasting and non-fasting periods in rural Tigray, Northern Ethiopia, and to identify associated factors. A community-based longitudinal study was carried out in Ethiopian Orthodox lent fasting and non-fasting periods. Using a multi-stage systematic random sampling technique, 567 and 505 children aged 6–23 months old participated in the fasting and non-fasting assessments, respectively. Statistical analyses were done using logistic regression, an independent sample t-test, Wilcoxon signed-rank (WSRT) and McNemar's tests. The prevalences of stunting, underweight and wasting were 31.6–33.7%, 11.7–15.7% and 4.4–4.8%, respectively. The weight-for-length (WLZ) and length-for-age (LAZ) values for children of fasting mothers were significantly lower ($p < 0.05$) compared to those of non-fasting mothers. Likewise, the median weight-for-age (WAZ) and diet diversity score (DDS) of children of fasting mothers were also significantly higher in non-fasting than in fasting periods. A small proportion of children (2.3–6.7%) met the minimum acceptable diet (MAD) in the study population, but these measures were significantly increased ($p < 0.001$) in the children of non-fasting mothers. Mother's fasting during lactation period of the indexed child was amongst the independent factors common in child stunting,

underweight and wasting. Nutritional status and feeding practices of 6–23-month-old children are affected by maternal fasting during the fasting period. Therefore, without involvement of religious institutions in the existing nutritional activities, reduction of undernutrition would not be successful and sustainable.

Keywords: stunting; wasting; undernutrition; minimum acceptable diet; minimum diet diversity; Tigray; Orthodox fasting; Ethiopia

3.1. Introduction

Despite the efforts undertaken globally, little has been achieved in reducing undernutrition with a sizeable gap from the global targets and goals still to fill. Worldwide, the number of stunted and wasted children under five years of age were about 154.8 and 52 million, respectively, in 2016, while more than 40 million children are overweight [1]. About 38%, 27% and 24% of stunted, wasted and overweight children under five years of age, respectively, were from Africa. Even worse, the number of stunted and overweight children increased by 9 and 9.8 million, respectively, between 2000 and 2016 [1]. The long-term impact of malnutrition on people's lives, most notably in health, education, and productivity, highly affects the human capital of a country. For example, an estimated loss of 4.7 billion US$ (equivalent to 16.5% of the national GDP) was recorded in 2009 due to child undernutrition in Ethiopia [2]. Therefore, the government of Ethiopia has been following different approaches to reduce maternal and childhood undernutrition significantly. Recently, the "Seqota" Declaration [2015–2030] was launched with the goal of eliminating all forms of malnutrition among children under age 2 by 2030 [3]. However, this cannot be achieved unless the socio-cultural and religious issues related with feeding practices are deeply investigated and addressed in Ethiopia, where more than 85 ethnic groups with diversified religious practices exist. As these practices have been passed from one generation to the next generation, they might have resulted in an intergenerational cycle of malnutrition. This could be worse in physiologically nutrient needy groups like pregnant and lactating mothers, and young and growing children.

Previous studies in Ethiopia and other parts of the world showed that maternal nutritional status and feeding practices are associated with growth indices of their children [4–8]. A more recent study by Desalegn and colleagues showed that maternal Body Mass Index (BMI) and dietary pattern of lactating mothers were negatively affected by maternal fasting status, and during Ethiopian Orthodox lent fasting period regardless of fasting status in rural Ethiopia [9]. Even if children are exempted from fasting, some mothers said that they were not happy to prepare food for them from animal sources as it could contaminate utensils for cooking family food [10]. Furthermore, a study on 6–23-month-old children of Ethiopian Orthodox mothers from the Gojam district also showed that mothers/caregivers who did not feed a diet containing animal products to their children due to fear of utensil contamination for family food preparation were less likely to feed the recommended dietary diversity. Economic limitations were a minor reason [11]. However, to the best of our knowledge, the effect of maternal fasting status and feeding practices on the nutritional status of the children and how these differ between fasting and non-fasting periods are not known. Therefore, the purpose of this study was to assess and compare the feeding practices and nutritional status of 6–23-month-old children of fasting and non-fasting lactating mothers during Ethiopian Orthodox lent fasting and non-fasting periods in rural Tigray of Ethiopia, where the majority are Orthodox religion followers.

3.2. Materials and Methods

3.2.1. Study Area, Design, Participants and Sampling

A longitudinal community-based survey was conducted in lent fasting (15 February–15 April 2017) and non-fasting (1–30 May 2017) periods in rural Genta Afeshum woreda (the third-level administrative division in Ethiopia), in rural Tigray, Ethiopia. The district is one of the hot spot areas of food insecurity and has a total population of 99,112 and 19 health posts to serve the community. Almost all people in the woreda belong to the ethnic group of Tigray and are followers of Ethiopian Orthodox Christianity.

For this study, the sample size was calculated using a single population proportion formula and considering the prevalence of stunting (57.1%) elsewhere in Tigray region [12], 95% of confidence interval for true prevalence and a relative precision (d) of 5%. The total population of children aged between 6–23 months old in the district was 4906, so that the finite source population size correction formula was used. Additionally, a 1.5 design effect and 10% non-response rate was used in the calculated sample size so as to get the final sample size of 575.

To obtain representative samples, multi-stage systematic random sampling was used. First, of the three woredas where the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ, Bonn, Germany) are implementing a nutrition sensitive agriculture (NSA) project in Ethiopia, Genta Afeshum was randomly selected. Then, seven kebeles (smallest administrative unit in Ethiopia) were selected randomly out of the twenty kebeles residing in the woreda. Children who were aged between 6–23 months, apparently healthy and breastfeeding during the study periods, were included, whereas children who were twins and whose mothers were not permanent residents of the study area during the study period were excluded from the study. Based on these, the list of children was prepared by the health extension workers in the selected kebeles, and finally the samples were selected using systematic random sampling methods.

3.2.2. Data Collection

Trained and experienced data collectors who are fluent in Tigrigna, Amharic and English languages were recruited. First, the questionnaire was prepared by the principal investigator, considering the information needed for the study, translated to the local language Tigrigna by a professional translator and pre-tested for its appropriateness. Using this, information on socio-demographic and economic characteristics, maternal and child characteristics, water, sanitation and health (WASH) and feeding practices was collected. The household food insecurity information was also collected using a household food insecurity access scale (HFIAS) standard questionnaire developed by Food and Nutrition Technical Assistance Project (FANTA) [13]. The weight of children was measured using a calibrated portable digital scale (Seca 770, Hanover, Germany) working with powered battery and measured to the nearest 0.1 kg. Likewise, the length of children was measured in a lying position with a wooden board to the nearest 0.1 cm. During weight and length measurements, the mothers were advised to remove their child's clothes and shoes until the child had only light clothes to minimize the weight and to get actual length, respectively. Duplicate measurements (length and weight) were carried out following standard procedures. Minimum diet diversity (MDD), minimum meal frequency (MMF) and minimum acceptable diet (MAD) of the children were computed from the two 24-h recall data points collected preceding the survey.

Ethical approval was obtained from the institutional review board of the College of Health Sciences at Hawassa University and Tigray region Health Bureau in Ethiopia and Ethics

Commission, Landesärztekammer Baden-Württemberg, Germany. Permission was also obtained from the Genta Afeshum woreda Health Office in the Tigray Province of Ethiopia. Additionally, the purpose of the study and the confidentiality of the information to be collected were explained to the mothers, and their agreement to participate with their indexed child in the study was documented by signing the informed consent. Each participating mother was also told that whenever the mothers felt they wanted to discontinue the participation with their child, withdrawal from the study was possible.

3.2.3. Data Management and Analysis

Before submitting the data, variable coding was conducted in SPSS for window version 20 (IBM Corporation, Armonk, NY, USA). Following this, the data were entered, cleaned and analyzed. First, frequency and crosstab were conducted to check completeness of data and to present the results in descriptive statistics (frequency and percent).

In our case, the diet diversity score was calculated as the summation of the number of food groups consumed for each of the two days, and averaged. Seven food groups were created, which included: grains, roots and tubers; legumes and nuts; dairy products; flesh foods; eggs; vitamin A-rich fruits and vegetables; and other fruits and vegetables. Likewise, meal frequency was computed as sum of the number of solid, semi-solid, or soft foods eaten by the child within 24-h for each of the two days, and averaged. A child who ate an average of at least four food groups in their meals of the two days fulfilled MDD. In breastfed children, the MMF was two times if aged 6–8 months and three times for 9–23 months. If a child fulfilled both the criteria for MDD and MMF, then he/she was considered as having met MAD.

The nutritional status (stunting, underweight and wasting) was identified using length-for-age, weight-for-age, and weight-for-length Z scores and compared with WHO reference data. For this, the length, weight, age and sex data of the children were entered in WHO Anthro software version 3.2.2 (World Health Organization, Geneva, Switzerland). A child who was below -2 standard deviations (-2SD) for WAZ, WLZ or LAZ was considered as stunted, wasted or underweight, respectively.

First, potential predicting variables for the outcome variables (stunting, underweight and wasting) were assessed from previous studies and included in bivariate analysis, and those with p-value < 0.25 were selected for multivariate logistic regression. Then, multi-collinearity was checked between the candidate variables separately for the three outcome variables using a variance inflation factor (VIF), and all were less than 10. Then, the candidate variables were entered in a multivariate logistic regression model with the stepwise forward Wald method. A p-value < 0.05 was used to declare the variables as predictors of the outcome variables. Hosmer and Lemeshow test and C-statistics (Area under the curve (AUC)) were used for model tests and were verified. Normality of continuous data was checked using the Kolmogorov-Smirnov test. An independent sample t-test was used to identify the difference between the children of fasting and non-fasting mothers' LAZ, WLZ and WAZ score values during the lent fasting period. Non-normally distributed data were analyzed using the Wilcoxon signed-rank test, whereas dichotomous data were analyzed by McNemar's test to identify the difference between children of fasting and non-fasting mothers' sub-groups dietary patterns between fasting and non-fasting periods.

3.3. Results

A survey was conducted with 567 children during Ethiopian Orthodox lent fasting with a response rate of 98.6%. Of those children who participated in the lent fasting survey, 505 were again involved in the non-fasting period, with a response rate of 87.8%. The reasons for excluding some children of the non-fasting period for the follow-up study were that some were older than 23 months or migrated with their family to other areas or were absent during the 2nd round survey.

3.3.1. Socio-Demographic Characteristics

In this study, almost all children belong to mothers who were from Ethiopian Orthodox Christians. Most of the mothers were house-wives, and more than half of the mothers were literate.

Table 3.1 Socio-demographic and economic characteristics of the study participants (n = 567) in rural Tigray, Northern Ethiopia (February–June, 2017).

Characteristics (*n* = 567)		**Number**	**Percent**
Religion of mother	Orthodox	565	99.6
	Other	2	0.4
Mother fasting during pregnancy period of indexed child	Yes	156	27.5
Mother fasting during lactation period of indexed child	Yes	176	31.0
Mother's education	Literate	369	65.1
Mother's occupation	Housewives	449	79.2
	Farmer	80	14.1
	Other	38	6.7
Family size	≤5	218	38.4
Household food security status	Food secure	166	29.3
Household toilet presence	Yes	455	80.2

About one-third of the mothers included in the study were fasting while they were pregnant and lactating. Only about one-third of 6–23-month-old children were from food secured and small family size households (HH) although most of them were from HH that owned toilets (Table 3.1).

3.3.2. Nutritional Status and Consumption Pattern

Almost all children included in this study consumed colostrum during the first few days after birth. More children were stunted (31.6–33.7%) than underweight (11.7–15.7%) and wasted (4.4–4.8%) in the study. Consumption of grains, roots and tubers, legumes and nuts, and fruits and vegetable foods was lower in children born of fasting than non-fasting mothers, both in fasting and non-fasting periods. Likewise, the proportion of 6–23-month-old children of non-fasting mothers who consumed dairy products, and food groups containing egg was higher compared to children of fasting mothers, both in fasting and non-fasting periods. Additionally, the proportion of 6–23-month-old children who consumed meat and vitamin A-rich fruits and vegetables was higher during non-fasting than fasting periods. Moreover, a lower proportion of 6–23-month-old children fulfilled the MMF, MDD and MAD standards during fasting (74.3%, 2.5% and 2.3%) than during non-fasting periods (75.0%, 6.9% and 6.7%), respectively (Table 3.2).

Table 3.2 Basic information, anthropometric status and consumption pattern of 6–23-month-old children in lent fasting and non-fasting periods in rural Tigray, Ethiopia (February–June, 2017).

		Lent Fasting Period (*n* = 567)			Non-Fasting Period (*n* = 505)		
		Children of Non-Fasting Mothers	**Children of Fasting Mothers**	**Total**	**Children of Non-Fasting Mothers**	**Children of Fasting Mothers**	**Total**
		N **(%)**	***N*** **(%)**	***N*** **(%)**	***N*** **(%)**	***N*** **(%)**	***N*** **(%)**
Age of child	≤12 months	168 (29.6)	71 (12.5)	239 (42.2)	103 (20.4)	45 (8.9)	148 (29.3)
	13–23 months	223 (39.3)	105 (18.5)	328 (57.8)	246 (48.7)	111 (22.0)	357 (70.7)
Sex of child	Male	215 (37.9)	104 (18.3)	319 (56.3)	190 (37.6)	93 (18.4)	283 (56.0)
	Female	176 (31.0)	72 (12.7)	248 (43.7)	159 (31.5)	63(12.5)	222 (44.0)
Colostrum intake after birth	Yes	381 (67.2)	169 (29.8)	550 (97.0)			
Stunted child		104 (18.3)	75 (13.2)	179 (31.6)	110 (21.8)	60 (11.9)	170 (33.7)
Underweight child		42 (7.4)	47(8.3)	89(15.7)	27 (5.3)	32 (6.3)	59 (11.7)
Wasted child		7 (1.2)	20 (3.5)	27 (4.8)	10 (2.0)	12 (2.4)	22 (4.4)
Grains, roots and tubers consumption		357 (63.0)	164 (28.9)	521 (91.9)	339 (67.1)	147 (29.1)	486 (96.2)
Legumes and nuts consumption		257 (45.3)	112 (19.8)	369 (65.1)	250 (49.5)	108 (21.4)	358 (70.9)
Other fruits and vegetables consumption		104 (18.3)	49 (8.6)	153 (27.0)	138 (27.3)	52 (10.3)	190 (37.6)
Dairy products consumption		33 (5.8)	15 (2.6)	48 (8.5)	41 (8.1)	9 (1.8)	50 (9.9)
Flesh foods consumption		0 (0.0)	3 (0.5)	3 (0.5)	4 (0.8)	4 (0.8)	8 (1.6)
Eggs consumption		71 (12.5)	34 (6.0)	105 (18.5)	87 (17.2)	38 (7.5)	125 (24.8)
Vitamin A-rich fruits and vegetables consumption		0 (0.0)	5 (0.9)	5 (0.9)	4 (0.8)	2 (0.4)	6 (1.2)
MAD		10 (1.8)	3 (0.5)	13 (2.3)	25 (5.0)	9 (1.8)	34 (6.7)
MDD		9 (1.6)	5 (0.9)	14 (2.5)	25 (5.0)	10 (2.0)	35 (6.9)
MMF		291 (51.3)	130 (22.9)	421 (74.3)	258 (51.1)	121 (24.0)	379 (75.0)

MAD = minimum acceptable diet; MDD = minimum diet diversity; MMF = minimum meal frequency; Fasting: Abstaining from eating any animal source foods during the seven official fasting periods of the Ethiopian Orthodox Tewahedo Church with/without abstaining from any foods and water until 12:00 noon and beyond of the fasting days; Fasting mother: a mother who usually abstained from eating any animal source foods (flesh foods, eggs and dairy products) during the official fasting periods of the Ethiopian Orthodox Tewahedo Church with/without abstaining from any foods and water until 12:00 noon and beyond of the fasting days, after the baptism day (40 and 80 days for a baby boy and girl, respectively) until the breast feeding indexed child was aged 23 months; Children of fasting mothers: Those children who were born of fasting mothers; Children of non-fasting mothers: Those children who were born of mothers who were not practicing fasting.

3.3.3. Factors Associated with Child Undernutrition

Children between 13–23 months of age were about 1.8 times more likely to be underweight than those who were between 6–12 months (AOR = 1.79 (1.07, 3.0)). Children who were born of mothers fasting during their pregnancy and lactation periods had 2.1 and 2.6 times higher odds of being underweight than those born of mothers not fasting during their pregnancy and lactation periods (AOR = 2.12 (1.29, 3.51) and AOR = 2.57 (1.56, 4.23), respectively). Children from illiterate and farming mothers were 1.8 and 2.3 times more likely to be underweight compared to those whose mothers were literate and housewives (AOR = 1.79 (1.10, 2.90) and AOR = 2.28 (1.25, 4.16), respectively]. Similarly, children between 13–23 months of age had 3.1 times higher odds of stunting than those between 6–12 months of age (AOR = 3.07 (2.04, 4.63)).

Children who did not consume colostrum after their birth were about 4.1 times as likely to be stunted compared to those who did (AOR = 4.10 (1.42, 11.82)). Additionally, children born of mothers fasting during their pregnancy and lactation periods were 1.8 times more likely to be stunted (AOR = 1.83 (1.21, 2.77)) than those children from mothers who did not fast during both periods (AOR = 1.81 (1.20, 2.72)). Furthermore, children living in households who did not own a latrine were 1.7 times more likely to be stunted compared to those owning a latrine (AOR = 1.67 (1.06, 2.64)). Children whose mothers were fasting during their lactation period and who were illiterate were 6.8 and 2.2 times more exposed to wasting when compared with the references (not fasting and literate, respectively) (Table 3.3).

Table 3.3 Multivariate logistic regression: associated factors of malnutrition of 6–23-month-old children regarding underweight, stunting and wasting in rural Tigray, Ethiopia (N = 567).

Variables	Predicting Category	OR	95% CI	*p*-Value
Underweight				
Age of child	13–23 months	1.79	1.07, 3.00	0.028
Mother fasting during pregnancy period of indexed child	Fasting	2.12	1.29, 3.51	0.003
Mother fasting during lactation period of indexed child	Fasting	2.57	1.56, 4.23	0.000
Mother's education	Illiterate	1.79	1.10, 2.90	0.019
Mother's occupation	Farmer	2.28	1.25, 4.16	0.021
Hosmer-Lemeshow test: p = 0.92, C-statistic: AUC = 0.73; 95% CI 0.68–0.79				
Stunting				
Age of child	13–23 months	3.07	2.04, 4.63	0.000
Child colostrum intake status	No colostrum after birth	4.10	1.42, 11.82	0.009
Mother fasting during pregnancy period of indexed child	Fasting	1.83	1.21, 2.77	0.005
Mother fasting during lactation period of indexed child	Fasting	1.81	1.20, 2.72	0.005
Toilet presence	No toilet in the household	1.67	1.06, 2.64	0.026
Hosmer-Lemeshow test: p = 0.98, C-statistic: AUC = 0.70; 95% CI 0.66–0.75				
Wasting				
Mother fasting during lactation period of indexed child	Fasting	6.78	2.78, 16.40	0.000
Mother education	Illiterate	2.24	1.01, 4.98	0.047
Hosmer-Lemeshow test: p = 0.47, C-statistic: AUC = 0.78; 95% CI 0.70–0.86				

AUC = Area under the curve; OR = Odd ratio; CI: Confidence interval.

3.3.4. Trend of Food Consumption Pattern and Nutritional Status of 6–23-Month-Old Children

Based on McNemar's test, there was no significant difference ($p > 0.05$) in the proportion of children born of fasting mothers who consumed from all of the seven food groups between the fasting and non-fasting periods. Likewise, the proportion of children of fasting mothers who fulfilled the MMF, MDD, and MAD criteria were not also significantly different ($p > 0.05$) between fasting and non-fasting period. However, the proportion of children of non-fasting mothers who consumed grains, roots and tubers, pulses and nuts, other fruits and vegetables, and egg food groups were significantly higher during the non-fasting period compared than the fasting period ($p \leq 0.001$, $p = 0.047$, $p \leq 0.001$ and $p = 0.017$, respectively). Similarly, the proportion of children who fulfilled the MDD and MAD were significantly increased in the non-fasting period compared to the fasting period, for the children of non-fasting mothers' group ($p \leq 0.001$) (Table 3.4).

Table 3.4 Food consumption pattern of 6–23-month-old children of fasting and non-fasting mothers during lent fasting and non-fasting periods in rural Tigray, Northern Ethiopia.

Parameters	Children of Fasting Mothers (*n* = 156)			Children of Non-Fasting Mothers (n = 349)		
	Lent Fasting Period	Non-Fasting Period	Significance	Lent Fasting Period	Non-fasting Period	Significance
	N (%)	*N* (%)	*p*-Value	*N* (%)	*N* (%)	*p*-Value
Grains, roots and tubers consumption	145 (92.9)	147 (94.2)	0.815 ns	317 (90.8)	339 (97.1)	0.000 *
Pulses and nuts consumption	97 (62.2)	108 (69.2)	0.228 ns	228 (65.3)	250 (71.6)	0.047 *
Other fruits and vegetables	45 (28.8)	52 (33.3)	0.427 ns	91 (26.1)	138 (39.5)	0.000 *
Dairy products consumption	14 (9.0)	9 (5.8)	0.332 ns	31 (8.9)	41 (11.7)	0.203 ns
Flesh food consumption	3 (1.9)	4 (2.6)	1.000 ns	0 (0.0)	4 (1.1)	NA
Eggs consumption	30 (19.2)	38 (24.4)	0.302 ns	64 (18.3)	87 (24.9)	0.017 *
Vitamin A fruits and vegetables	5 (3.2)	2 (1.3)	0.453 ns	0 (0.0)	4 (1.4)	NA
MAD	3 (1.9)	9 (5.8)	0.146 ns	7 (2.0)	25 (7.5)	0.001 *
MDD	5 (3.2)	10 (6.4)	0.302 ns	6 (1.7)	25 (7.2)	0.001 *
MMF	114 (73.1)	121 (77.6)	0.349 ns	256 (73.4)	258 (73.9)	0.927 ns

Data analysis using McNemar's test, significant level at p < 0.05; NA = the data were not appropriate for analysis; MAD: minimum acceptable diet, MDD = minimum diet diversity, MMF: minimum meal frequency; ns- not significantly different at p < 0.05; * = significantly different at p < 0.05.

Likewise, the WAZ, WLZ and LAZ of children of non-fasting mothers were significantly higher than those of children of the fasting sub-group during the lent fasting period ($p \leq 0.001$, $p \leq 0.001$ and $p = 0.003$, respectively) (Table 3.5). A Wilcoxon signed-rank test showed that except for the median of WAZ ($p = 0.153$) for children of the non-fasting mothers' sub-group, the median WAZ ($p = 0.034$) for the children of fasting mothers, and the DDS of both, the children of the fasting and non-fasting mothers' sub-groups were significantly increased in the non-fasting than in the fasting period ($p \leq 0.001$) (Table 3.6).

Table 3.5 Anthropometric measurements (WAZ, WLZ and LAZ) of 6–23-month-old children of fasting and non-fasting mothers in the lent fasting period in rural Tigray, Ethiopia.

Variables	Fasting Mother (*N* = 176)	Non-Fasting Mother (*N* = 391)	*p*-Value
	Mean (Standard Deviation)	Mean (Standard Deviation)	
WAZ	−1.25 (1.15)	0.77 (1.09)	0.000 *
WLZ	−0.58 (1.15)	−0.19 (1.06)	0.000 *
LAZ	−1.60 (1.35)	−1.24 (1.34)	0.003 *

LAZ = length for age; WLZ = weight for length; WAZ = weight for age; data analysis using independent sample t-test, significance level declared at $p < 0.05$; * = significantly different at $p < 0.05$.

Table 3.6 Comparison of 6–23-month-old children's WAZ and DDS values between lent fasting and non-fasting periods in rural Tigray, Ethiopia

Variables	Data Collection Period						
	Lent Fasting			Non-Fasting			
	Mean (SD)	Median (IQR)	Range (Min, Max)	Mean (SD)	Median (IQR)	Range (Max, Min)	Sign
Children WAZ of fasting mother	−1.25 (1.14)	−1.22 (−2.03, −0.54)	−4.33, 2.52	−1.16 (1.14)	−1.11 (−1.83, −0.46)	−4.37, 3.83	0.034 *
Children WAZ of non-fasting mother	−0.74 (1.08)	−0.79 (−1.48, −0.07)	−4.97, 2.70	−0.66 (1.02)	−0.69 (−1.32, −0.11)	−0.5.08, 2.32	0.153 ns
Children DDS of fasting mother	2.09 (1.02)	2.00 (1.50, 2.50)	0.00, 7.00	2.43 (0.93)	2.50 (2.00, 3.00)	0.00, 4.5)	0.000 *
Children DDS of non-fasting mother	2.04(0.88)	2.00(1.50, 2.50)	0.00, 5.00	2.50 (0.95)	2.50 (2.00, 3.00)	0.00, 7.00	0.000 *

Fasting mothers (n = 156); non-fasting mother (n = 349); data analyses using the Wilcoxon signed-rank test, significant level at $p < 0.05$; WAZ = weight for age; DDS = diet diversity score; ns- not significantly different at $p < 0.05$; * = significantly different at $p < 0.05$.

3.4. Discussion

This is the first time a study has assessed feeding practices and nutritional status of 6–23-month-old children of fasting and non-fasting mothers during the Ethiopian Orthodox lent fasting and non-fasting periods in rural Tigray, Ethiopia. Socio-economic factors, which are possibly associated with stunting, underweight and wasting, were also determined.

3.4.1. Food Consumption Pattern of 6–23-Month-Old Children

According to the UNICEF conceptual framework of malnutrition, inadequate dietary intake is one of the immediate causes of child malnutrition [14]. In our study, cereals, roots and tubers, and pulses and nuts are the food groups majorly prepared for the 6–23-month-old children in the rural Tigray in Ethiopia, regardless of fasting period. This result is consistent with previous studies in Ethiopia [11,15–20]. A similar finding was reported on the consumption of grains, roots and tubers for children from Vietnam, Bangladesh, Pakistan, Indian and the U.S. [21–25]. According to Demissie and his colleagues [21], consumption of fruits and vegetables is sub-optimal in the Tigray region and Ethiopia in general [26]. Supporting this evidence, we also found that only 1% of children consumed vitamin A-rich fruits and vegetables. The result is also comparable with a previous study in rural Tigray [27]. However, our finding was lower than findings of two national surveys [14.8, 27.7%] in Ethiopia and Pakistan (18.7%) [22,28,29]. This could be related to the fact that cultivation on the farm and availability in the markets are rare in the study area, probably resulting in a less diverse diet. Another explanation could be a difference in feeding practices [26]. However, the consumption of other fruits and vegetables food group was between 27.0–37.6% in the present study. This result is higher than national figures, which are 3.3% and 10.1% [28,29].

Animal source foods are both energy and nutrient dense, and an excellent source of high quality and easily digestible protein, in addition to being an efficient and easily absorbable source of micronutrients like iron, zinc, vitamin A, vitamin B12, riboflavin and calcium [30]. In the present study, the consumption of a diet composed of flesh foods was 0.5% and 1.6% in fasting and non-fasting periods, respectively. These results are comparable with a previous study during the Ethiopian Orthodox fasting period in the Dejen district (0.0%), and studies conducted in

Gobalafto district in North Wollo (0–5%), Wolaita district (1.6%), and findings of the Ethiopian national food consumption survey for all regions in the country (0.1–0.6%) [11,15,31,32]. However, our finding was lower than a study conducted in the Arsi-Negele district of Oromia region, in Ethiopia (11.3%) and Mongolia (4–14%([33,34]. This might be due to the fact that the area of the later studies has animal husbandry potential and cultural and eating habit differences. In the current study, consumption of dairy products was between 8.5% and 9.9% in fasting and non-fasting periods, respectively. Almost comparable proportion of 6–23-month-old children (7.5%) of the Dejen district consumed dairy products in the fasting period in North-west Ethiopia [11]. However, the findings in the present study were lower than in studies conducted in Amhara (about 20.0%) and Oromia (52.4%) regions, and Addis Ababa City (70.4%) in Ethiopia and Pakistan (50.5%) [17,20,22,34]. An explanation for this could be that the studies were conducted in different periods, and dairy products were the second most common foods groups consumed by the Pakistan children. In the present study, the proportions of children who consumed egg in the days before the surveys of fasting and non-fasting periods were 18.5% and 24.8%. However, these were lower than in similar studies in the Amhara region, which was 98.0%, where fasting of Ethiopian Orthodox religion is routine in the fasting days of the year. This could be due to more chickens in the households included in the later study, which may result in availability of eggs for children during the fasting period and household consumption in general. The consumption of egg in our finding was higher than the national findings of the last two Ethiopian demographic and health survey (DHS) studies (8.3%, 17%) and study in Amhara region (<10.0%) in Ethiopia [15,28,29]. However, it was consistent with a study conducted in the Arsi-Negele district (22.3%) of Oromia region, in Ethiopia [34].

Minimum meal frequency is a proxy indicator to determine whether the energy requirement of a child is met and examines the frequency of meals where the children received foods other than breastmilk, considering specific age and breastfeeding status of the child [29]. In this study, three-fourths of children of fasting and non-fasting mothers had eaten the minimum number of meals in the days preceding the fasting and non-fasting surveys. This result is in line with studies conducted in the Dabat (69.3–75.0%) and Gorche (78.0%) districts of northern and southern Ethiopia, respectively [35,36]. However, our finding is higher than studies in Kemba (14.5–33.6%), Bale (44.7%), Arsi-Negele (67.3%), Wolaita (69.3%) districts, elsewhere in Tigray region (66.0%) and findings for the Tigray region (55.6%, 49.4%), and national averages (47.9%, 44.6%) in Ethiopian DHS studies of 2011 and 2016, respectively, and Pakistan (38.2%) [16,19,28,29,34,37,38]. However, it is lower than findings on children from the South Wollo district, in Ethiopia, which were 91.0–97.0% and Nepal (87.8–98.2%) [15,39].

Minimum dietary diversity is one of the indicators to assess the quality of food consumed by 6–23-month-old children. Consumption of at least four different food groups in a day is the minimum requirement [29,40]. In this study, the proportion of children who consumed foods prepared from at least four diversified food groups (MDD) was 2.5% and 6.9% in fasting and non-fasting periods, respectively. This finding indicates that children aged 6–23 months in the study area are consuming a poor quality complementary diet. A study conducted in 6–23-month-old children of Orthodox Christian mothers in Gojam indicated that 13.6% had four diversified food groups in the food they consumed preceding the survey during the fasting period [11]. Similarly, our findings are also lower than findings in children living in the Gorche (10.4%), Kemba (23.3%), Bale (28.5%), and Wollo (23.0–41.0%) districts in Ethiopia, India (38%), Bangladesh (48.4%) and Vietnam (83.2%) [15,16,25,35,41,42]. Generally, these findings indicate that undernutrition specifically stunting and micronutrient deficiencies could be the public health problem in the area. This is supported by studies conducted in children from different parts of the world and ours [43–46].

For appropriate growth and development, infants and young children should be fed with at least four diversified food groups from the minimum number of meals (MAD) recommended according to specific to the age and breastfed status of the child [40]. In the present study, the proportion of 6–23-month-old children who met both the minimum diversity and the number of meals (MAD) preceding the surveys was 2.3–6.7% in the study population. The result is consistent with DHS 2011 and 2016 findings for the Tigray region (4.5% and 5.7%, respectively) and the national figure (4.0%) in DHS 2016 for Ethiopia [28,29]. However, it is lower than research findings conducted in three districts (17.0%) of the Tigray region, in northern Ethiopia, India (9%), Nepal (32%), Bangladesh (40%) and Sri Lanka (68%) [31,38,47]. Moreover, the proportion of 6–23-month-old children who fulfilled the criteria for MAD was higher for non-fasting mothers (2.0–7.5%) and in non-fasting period (6.7%) compared with their counterparts. This finding suggests that activities which can improve the child feeding practices should include improving maternal feeding behavior, as many scholars evidenced their association, including ours [9,21,48].

3.4.2. Nutritional Status of 6–23-month-Old Children

In the present study, the prevalence of wasting, underweight and stunting in the 6–23 months old children was between 4.4–4.8%, 11.7–15.7% and 31.6–33.7%, respectively. These results are lower than the findings for the Tigray region and national figures in last two DHS studies in Ethiopia. For example, wasting, underweight, and stunting in under-five aged children were

10.3% and 9.7%, 35.1% and 28.7%, and 51.4% and 44.4% in DHS 2011 (Tigray region and national, respectively). Except for wasting, these figures further decreased to 23.0% and 23.6% for underweight, and 39.3% and 38.4% for stunting in the DHS 2016 study [28,29]. This could indicate an improvement in child nutritional status, both regionally, and at the national level.

In this study, the median WAZ of children of fasting mothers was lower compared to children of non-fasting mothers, both in fasting and non-fasting periods. The WAZ of children from non-fasting mothers' sub-group also improved during the non-fasting period. Similarly, the prevalence of underweight children from the fasting sub-group was higher than that of children from the non-fasting sub-group, in both periods. Likewise, the mean standard deviations (SD) of WAZ, WLZ and LAZ of children from the fasting mothers sub-group were lower compared to children from non-fasting mothers during the fasting period. Similarly, the proportion of wasted children was higher in the fasting sub-group compared to those children from non-fasting mothers during the fasting period. Conversely, relatively more children from non-fasting mothers were stunted than from fasting mothers. This could be due to the higher number of older children in the non-fasting group. Similar findings were observed in studies conducted in the Tigray region, northern Ethiopia [4]. Multivariate logistic regression showed that children of mothers who fasted during the pregnancy and lactation period were more likely to be undernourished (stunting, underweight, and wasting) than those children of mothers who were not fasting in the same periods. These indicate that, maternal fasting during pregnancy, and lactation not only affect the nutritional status of the mother themselves [9], but also their fetus/breastfed child. To increase the awareness on the effect of fasting practices on the undernutrition, the Ethiopian Orthodox Church (EOTC) with the United States Agency for International Development (USAID) multi-sectoral nutrition project, Empowering New Generations to Improve Nutrition and Economic opportunities (ENGINE) held a consultative meeting with religious leaders and church scholars to clarify fasting practices for children, pregnant and lactating women in line with religious guidelines. This was done after a sermon guide was developed in 2016, based on the church teachings and outlining the laws and regulations related with fasting and nutrition. According to the joint press release by EOTC and USAID/ENGINE, the sermon guide highlighted the exemption of mothers and their babies from fasting during the first 1000 days [49]. The sermon guide also emphasized the cooking utensils to be used for complementary food preparation during fasting seasons, as many mothers were not happy to prepare complementary food from the animal sources during fasting seasons due to fear of contamination of family food [10]. Therefore, strengthening the activities started by the Church and the involvement of religious institutions and leaders in the existing national multi-sectoral approach activities would accelerate and sustain the reduction of nutrition-related problems in the country.

Previous studies in Africa and Southeast Asian countries demonstrated that children in the age between 13–23 months were more associated with underweight and stunting compared to those who were aged 6–12 months [28,29,50–61]. Similar findings were also revealed in our study. This could be related to feeding practices, contamination and poor quality complementary food, which is mainly cereal based [4]. Similarly, maternal illiteracy was found to be a predictor variable for underweight and wasting. The former result is consistent with previous studies in Ethiopia and other low and middle income countries [28,29,62–65]. Similarly, findings in Ethiopian DHS also showed that childhood wasting was associated with maternal illiteracy [28,29]. This indicates that educating mothers will be an important activity for improving the nutritional status of children in a given community. Likewise, compared to children whose mothers were housewives, children of farmer mothers were more exposed to being underweight.

This might be related to less time allocation for child care due to a high work load and absence from the home. Farm work also expends more energy, and mothers may be more frequently exhausted, which could result in poor appetite and might affect the quality and quantity of breast milk. Moreover, children who did not take the first milk (colostrum) after their birth were more stunted than those who did. This could be related to infection emanating from pre-lacteal foods, which is a predictor for child stunting in North-west Ethiopia [58]. Therefore, activities which improve the colostrum intake (e.g.,- antenatal care) should be done in the study area [66]. Furthermore, children who were living in households without toilets were more exposed to stunting compared to those from households owning toilets. This could be related to poverty in general, a well-known factor for malnutrition. Additionally, contamination of the soil due to open defecation increases the risk for frequent episodes of childhood diarrhea, which has a negative impact on the nutritional status of sub-Saharan African children [50].

However, this study has the following limitations: This study considered only the lent fasting period, among the seven official fasting periods in Ethiopian Orthodox religion. It also included only children aged between 6–23 months, out of those children below seven years of age, who are exempted from the official fasting in the religion.

3.5. Conclusions

This study showed that there is high prevalence of stunting (31.6–33.7%), underweight (11.7–15.7%), and wasting (4.4–4.8%) in the study area; however, these values are lower than those reported earlier in the Tigray region (39.3%, 23.0% and 11.1%), and of national figures (38.4%, 23.6% and 9.9%). These are indications of improvement of child nutrition in rural Tigray. However, the prevalence’s are still higher, both in children of fasting mothers and the study population especially during Ethiopian Orthodox lent fasting period. Thus, religious fasting should not go against the existing nutritional intervention modalities. Mother's fasting during the lactation period of an indexed child was the common predictor for child stunting, underweight and wasting. Maternal illiteracy and age of children and maternal fasting during pregnancy of indexed children were also common variables affecting combined effects of underweight and wasting, and underweight and stunting, whereas, the type of job of mothers and lack of colostrum feeding of children after birth were associated with underweight and absence of a toilet in the household with the stunting of children. Hence, improving maternal education and reducing the work burden in farming activities or promotion and support of mothers in off-farm income generation nearby their households are recommended. Improving household latrine coverage and breastfeeding of colostrum should be encouraged and strengthened. 'Grains, roots, and tubers' was the most frequently eaten food group by 6–23-month-old children, followed by 'legumes and nuts' and then 'other fruits and vegetables'. Therefore, to increase nutrients and improve the palatability of grains and legumes, traditional food processing techniques like dehulling/dehusking, soaking and germination, and slightly roasting are crucial. Additionally, the proportion of children who consumed dairy products, flesh foods and eggs who met the MDD was small. The average DDS of the children was also low, being worst in children of fasting mothers especially during the lent fasting period. Thus, regardless of the fasting period, diet diversity should be properly addressed in preparation of complementary foods by incorporating animal products [dairy products; flesh foods; eggs], vitamin A-rich fruits and vegetables. In general, nutritional status is affected by maternal fasting status during pregnancy and lactation periods, and during the lent fasting period in rural Tigray, Ethiopia. Therefore, without strengthening and involvement of religious institutions and leaders in the existing nutrition improvement activity by the Church and in the National Nutrition Program (NNP) of, in particular nursing mothers and growing children, reduction of undernutrition would not be successful and sustainable. As this study is focused on the food consumption and growth index pattern of 6–23-month-old children, further studies on physiological consequences of levels of micronutrients or bio-markers are recommended.

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3.6. References

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Chapter 4

Paper III

4. Calculator for Inadequate Micronutrient Intake (CIMI): Validation of the Software in 12-23-Months-old Children and Lactating Women of Rural Ethiopia

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Calculator for Inadequate Micronutrient Intake (CIMI): Validation of the Software in 12-23-Months-Old Children and Lactating Women of Rural Ethiopia

Abstract

Background: Religion and religious activities like fasting play a pivotal role in the dietary pattern of an individual in countries like Ethiopia. However, micronutrient intake and its effect during Ethiopian fasting vs. non-fasting periods have not been assessed. Many of the dietary assessment studies in Ethiopia use only diet diversity score (DDS), a proxy indicator for micronutrient adequacy because most of the quantitative dietary assessment techniques are time consuming and need experts to calculate dietary intake. Therefore, the objective of this study was to assess the dietary nutrient intakes of 12-23-months-old children and lactating women at fasting vs. non-fasting period in rural Ethiopia; to be able develop and validate a Calculator for Inadequate Micronutrient Intake (CIMI) program, which is a simple, easy-to-use app based on amounts of different food and beverage groups which calculates dietary micronutrient intake of an individual. Methods: A community-based longitudinal assessments were conducted using 12-23-months-old children and lactating women in lent fasting (n=377 and 568) and non-fasting (n=404 and 518) periods in rural Ethiopia. Statistical analyses were performed using SPSS and Excel. For validation, individual nutrient intake was analyzed by two different methods: CIMI and the established nutrition assessment software NutriSurvey (NS). Afterwards, average mean intake and percentage of participants identified with an inadequate intake of <2/3 of recommended nutrient intake (RNI) were compared using the two methods. Results: Energy and almost all macro- and micronutrients intakes of children and women were lower in lent fasting period compared to non-fasting. Likewise, the prevalence of inadequate intake of energy, protein and most micronutrients were higher in both children (1.7-9.1%) and lactating women (1.6-21.4%) during lent fasting than non-fasting period. Based on CIMI and NS calculations, average dietary nutrient intake for children (R=0.741-0.956) and lactating mothers (R=0.779-0.920) were comparable. Conclusion: More attention should be given to nutrition intervention related to diet improvement activities of young children and lactating women especially during religious fasting periods. CIMI developed for the rural Ethiopian setting estimates the average nutrient intake accurately; and identifies inadequate micronutrient intake of individuals using the RNI of FAO/WHO enabling enumerators to provide feedback and suggest improvements.

Keywords: lent fasting; children; lactating mothers; CIMI; micronutrient; dietary intake; Ethiopia

4.1. Introduction

Religious fasting plays a pivotal role for changing the dietary pattern of households, as a result the nutritional status of individuals living in the households, especially nutritionally vulnerable children and women [1–4]. In Ethiopia, more than two-third of the population are either a follower of Ethiopian Orthodox or Muslim, who practice a strict fasting during their religious fasting periods [5]. But, the fasting traditions and the number of fasting days in the calendar year are prominently different between these two religions [6]. In Ethiopian orthodox religion, lent fasting is the longest among the seven official fasting periods. In this term, abstaining from any animal source foods completely, and any foods and water for at least some hours daily, except Saturday and Sunday is religious obligatory. Accordingly, studies in the 6-23-months-old children and lactating mothers in Ethiopia indicated that maternal and child undernutrition and consumption of foods prepared from low diverse food groups were higher in lent fasting compared to non-fasting period in rural Ethiopia [1,2]. To the best of our knowledge, there is no study which has assessed the dietary micronutrient intake of Ethiopian Orthodox women and their children.

For appropriate growth and development, micronutrients are crucial apart from the macronutrients (carbohydrates, proteins and fats) [7]. The inadequate intake of these micronutrients below the amount required leads to the invisible form of malnutrition called micronutrient deficiency or 'Hidden hunger' [8]. If this inadequate supply of micronutrient persists for a longer period, then it will be increasing the risk of disease, growth and cognitive development impairment at the early stage of childhood, and maternal illness and decrease their life expectancy. Therefore, early identification of micronutrient deficiencies will be an important step to design and initiate appropriate prevention and intervention activities. But these are lacking, because quantitative nutrient intake data are often not available. As many of the existing dietary nutrient intake assessment techniques (food frequency questionnaires (FFQs), food weight record and 24-h recall) are time consuming, need well trained field workers during the surveys and an expert to calculate dietary intake using a nutrition software and identify undernutrition. Alternatively, many researches use different types of diet diversity scores as proxy indicator for dietary adequacy. These might be one of the reason why hidden hunger is not addressed properly in Ethiopia and other African countries, where this phenomenon remains high and persistent at large [9]. Thus, developing a tool that can evaluate the nutrient intake and detect the gap between the nutrient intake and the recommended intake, but easy-to-use, fast and applicable in rural poor setting is important to early identify the problem, set an appropriate prevention and intervention activities and monitor the progress.

The Calculator for Inadequate Micronutrient Intake (CIMI) is a simple, easy-to-use, informative, web-based application method, which was first developed using commonly consumed

Indonesian foods for Indonesian population. CIMI calculates energy and nutrient intake accurately, and identifies nutrient inadequacy according to FAO/WHO recommended nutrient intake (RNI) regarding age, sex and physiological stage [10]. Therefore, the purpose of this study was

1) to assess the dietary nutrient intakes of 12-23-months-old children and lactating women during Ethiopian Orthodox fasting and non-fasting periods, in rural Tigray, North Ethiopia

2) to adapt and validate CIMI, a simple, easy-to-use, informative, web-based application method which can calculate the micronutrient intake of Ethiopian population based on their traditional dietary patterns.

4.2. Materials and Methods

4.2.1. Study Area, Design, Participants, Sampling and Ethical Clearance

The survey was conducted during lent fasting and non-fasting period in Rural Genta Afeshum woreda of North Ethiopia, between February–April and May 2017, respectively. Description of the whole study areas, sample size calculations, sampling methods, inclusion and exclusion criteria and ethical issues were published, elsewhere [1,2]. However, in this study, the children between 6-11-month and > 23 months of age in either of the surveys, and those lost for follow-up study were excluded and thus the final total sample size was reduced to 377 and 404 in lent fasting and non-fasting assessments, respectively. Those children who were < 12-month in the lent fasting but aged ≥ 12-month in the non-fasting period were included in the study. Lactating mothers also participated in the present study in lent fasting (n=568) and non-fasting periods (n=518). The lactating mothers participated in the lent fasting period, but their children > 23 months of age were excluded from the survey during non-fasting period.

4.2.2. Data Collection

Before conducting the quantitative dietary survey, the principal investigator identified food items, recipes, cooking and serving materials and how they were served commonly for the children and women in the study area. Food items were measured using a laboratory weight balance (2 kg maximum weight: Model CS 2000, Ohaus Corporation, Newark, NJ, USA). Then, common food pictures and utensils were also used to support the mothers for estimating the amount of food consumed by them and their children. Following this, trainings were given for the 10 experienced data collectors who participated in the surveys. Details about the data collectors and the questionnaires used are found in previous published articles [1,2].

4.2.3. Development of Calculator for Inadequate Micronutrient Intake (CIMI) for Ethiopia

Before structuring the food groups for the CIMI program, the type of food items commonly consumed in Ethiopian population were identified from Socio-economic survey dataset (2016) based on the amount consumed in kg per capita per day. Beside this, we also reviewed literatures and published articles which provide information related to food consumed in Ethiopia. Accordingly, 93 food items were identified and categorized into 31 food groups (Table 4.1). Then, the energy, macro-, and micro-nutrients composition of each food item in the 31 food groups was adopted from Ethiopian composition table III and IV, published articles elsewhere in Ethiopia or Kenyan food composition tables [11]. Additionally, missing nutrients were taken from US Department of Agriculture database (USDA) 2018. Based on this, the nutrient profile of each food group was identified, using the share contribution of each food item contributing to the specific food group and calculated accordingly. Following this, the amount of nutrient intake was calculated by CIMI out of the sum of nutrient intakes of all food groups. An algorithm for classifying the bioavailability of iron and zinc was adapted from CIMI developed for Indonesia [10]. Then, CIMI automatically calculated the absolute intake and percent of RNI fulfillment of energy and each of the 14 nutrients included.

4.2.4. Data Management and Analyses

The 93 food items considered for the development of CIMI for Ethiopia with their nutrient compositions were entered in NutriSurvey (NS) software version 2007 as database for analysis. Beside for the development of CIMI software, CIMI server was created. The purpose of this server is to store the dietary data entered in the CIMI software after the data automatically synced when the tablet gets Wi-Fi network. Then, the estimated amount of food items consumed in the last 24 hours by the children and women involved in this study were entered in NS, which calculated the nutrient intake. However, the estimated amount of food items was sorted into the 31 food groups categorized and summed up together to get the amount consumed as a food group and then entered into CIMI software. NS is an internationally established nutritional assessment software. In this software, each food item eaten has to be entered with the estimated amount individually. Data entries on NS were carried out by the principal investigator, but for CIMI, five experienced data entrant were trained and entered the data. Then, the tablets with CIMI data were synced in the Wi-Fi network to the server daily after the data entry and finally the results were downloaded from the server. Following these, variables coding, data transfer, cleaning and completeness of data were carried out in SPSS for window version 20 (IBM Corporation, Armonk, NY, USA), consecutively. The average nutrient intakes and the number/percentage of participants below the inadequate intake cutoff of <2/3 RNI were calculated both for NS and CIMI software's. Specifically, for iron and zinc, the RNI could be different because only CIMI considers different bioavailability levels, as a result the cutoff differs for individuals. The average mean differences (Z) of each nutrient intake was calculated as an average of the mean difference results obtained by subtracting the results produced by CIMI (Y) from NS results (X) of the participants included in the study (**Equation a**), and the average mean difference % (R) for each nutrient was calculated as the average mean difference (Z) divided by the average nutrient result produced by NS and then multiplying the dividend by 100 (**Equation b**).

$$Z = \frac{\sum_{i=1}^{n}[X_i\text{-}Y_i]}{n} \quad \text{[Equation a]} \qquad\qquad R = \left[\frac{Z}{\frac{\sum_{i=1}^{n} X_i}{n}}\right]*100 \quad \text{[Equation b]}$$

where Z is the average mean difference of each nutrient and energy, X is the nutrient value of each participant calculated by NS, Y is the nutrient value of each participant calculated by CIMI, n is the number of participants, R is the average mean difference % of each nutrient and energy.

Based on this, the mean difference % expressed in terms of NS was used to categorize the nutrient intake result produced by CIMI as very high accurate (+/-0<5%), good accuracy (+/-5-15%) moderate accuracy (+/-15-30%) and low accuracy (+/->30%) [12]. Additionally, the correlation on each nutrient intake results between CIMI and NS for 12-23-months-old children and lactating women were analyzed using Pearson correlation test at the significance level of p=0.001. Microsoft Excel 2010 was also used to compute dietary intake data.

Table 4.1 Description of the food groups in CIMI Ethiopia

Food group	Foods contributed to the calculation of the average nutrient content of the food group
White maize	White maize
Yellow maize	Yellow maize
Wheat	Wheat
Sorghum and millet	Sorghum and Finger millet
Red teff	Red Teff
White teff	White teff
Barley and related	Barley, Rice and Oats
Beans	Haricot bean, Broad bean, Chickpea, Pea, Lentil, Kidney bean, Soybean and Vetch
Oil seeds	Linseed, Niger seed, Peanut, Sesame seed, Sunflower seed, Safflower seed, Amaranth seed and white Fenugreek
Kocho and bulla	*Bulla* and *Kocho*
Potato and related	Irish potato, Sweet potato, Yam, Cassava, Taro, Anchote and *Amicho*
Meat	Goat meat, Sheep meat, Beef meat and Chicken meat
Fish	Fish
Egg	Chicken egg
Milk	Milk, cow
Cheese	Cheese, cow
Butter and oils	Butter, Vegetable oil and Palm oil
Sugar and honey	Sugar and Honey
Sugarcane	Sugarcane
Moringa	Moringa
Carrot and related	Pumpkin and Carrot
Green leaves	Chard, Lettuce and Ethiopian kale
Green pepper and related	Green pepper and Garlic
Pepper powder	Pepper powder
Other vegetables	Tomato, Onion, Cabbage, Beets and Snap bean (Fossolia)
Mango and related	Mango, Papaya, Guava and Apricot
Banana	Banana
Orange and related	Orange, Mandarin, Avocado, Pineapple, Apple, Strawberry, Lemon, Cactus, Passion fruit, Custard apple, Watermelon, Peach and Pomegranate
Coffee and tea	Tea and Coffee
Coca Cola and Mirinda	Berez, Coca Cola, Pepsi Cola, Fanta, Mirinda and Sprite
Mild alcohol	Beer, *Tella*, *Tej* and *Borde*

4.3. Results

Among the 12-23-months-old children, 166 (44.0%) in fasting and 182 (45.0%) in the non-fasting period assessed were females. The mean age of the children and mothers during fasting and non-fasting periods were 16.8 ±3.3 and 17.6 ±3.5 months; and 29.8± 6.34 and 29.8 ±6.4 years, respectively. The median LAZ, WAZ and WLZ for the children were -1.70, -1.07 and -0.42, respectively and the BMI for the mothers was 19.27 during the lent fasting period. But the WAZ and BMI were improved in the non-fasting period to -0.91 for the children and to 19.3 for mothers (Table 4.2).

Table 4.2 Socio-demographic characteristics of the participants involved in the study in rural Southern and Northern Ethiopia

Variables		Northern Ethiopia	
		Fasting season*	Non-fasting season**
		N (%)	N (%)
Sex of children (n=377*, 404**)	Female	166 (44.0)	182 (45.0)
	Male	211 (56.0)	222 (55.0)
Mean age of women (years) (n=568*, 518**)		29.8 (6.3)	29.76 (6.4)
Mean age of children (months) (n=377*, 404**)		16.8 (3.3)	17.60 (3.5)
Nutritional status of children (n=373*, 386**) Median (SD)	LAZ	-1.70 (-2.45, -0.96)	-
	WAZ	-1.07 (-1.78, -0.46)	-0.91 (-1.50, -0.28)
	WLZ	-0.42 (-1.11, 0.22)	-
Nutritional status of women Median (SD) (kg/m^2) (n=566*, 517**)	BMI	19.3 (17.9, 21.0)	19.3 (17.9, 21.2)

The median intake of energy, calcium, iron, zinc, vitamin B1, niacin and vitamin C 24-hr prior to the start of the survey were below the standard estimated for the 12-23-months-old breastfeeding children considering the low bioavailability of iron and zinc, in both fasting and non-fasting periods, according to NS and CIMI software's. But, the estimated need for protein and vitamin A were fulfilled in both study periods, except for vitamin A calculated by CIMI. Likewise, the median intake of energy, calcium, zinc, vitamin C, vitamin A and niacin (except for non-fasting using NS) for the lactating mothers were below the RNI standard in both the study periods. However, the dietary protein, iron and vitamin B1 intakes satisfied the RNI standard for the same group, regardless of the study periods. Furthermore, except vitamin A, the other macro- and micro-nutrients and energy intakes calculated by the CIMI and NS software's were comparable. Moreover, the energy, protein and all other micronutrients intakes were improved during non-fasting than fasting period in both study groups (Table 4.3).

Table 4.3 Average intake of energy and nutrients in 12-23 months old children and lactating mothers calculated by NS and CIMI

		Children (12-23months)				Lactating women			
Nutrients		**Fasting season (n=377)**		**Non-fasting season (n=404)**		**Fasting season (n=568)**		**Non-fasting season (n=518)**	
		NS	**CIMI**	**NS**	**CIMI**	**NS**	**CIMI**	**NS**	**CIMI**
Energy (kcal)	Mean (SD)	482 (267)	477(325)	532 (331)	529 (356)	1891(717)	1838 (706)	2150(530)	2079(502)
	Median (25th, 75th)	457(302, 637)	431 (270, 625)	489 (330, 653)	475 (315, 630)	1930(1313, 2358)	1871(1283, 2299)	2123 (1812, 2277)	2092(1750, 2398)
Protein (g)	Mean (SD)	13.9 (8.8)	14.8 (11.6)	14.7(9.6)	15.3(11.0)	57.0 (25.4)	58.7(27.9)	61.2 (16.3)	60.6 (15.9)
	Median (25th, 75th)	12.2 (8.0, 18.5)	12.4 (7.1, 18.9)	13.0 (8.9, 18.4)	12.6 (8.9, 19.1)	55.9 (36.1, 74.5)	57.1 (36.2, 77.9)	59.9 (50.7, 70.6)	60.8 (50.1, 70.5)
Iron (mg)	Mean (SD)	8.5 (5.0)	9.5 (7.5)	9.3(6.3)	10.0 (7.3)	36.7 (16.1)	38.4 (17.3)	41.5 (12.8)	41.5 (13.4)
	Median (25th, 75th)	7.7 (5.0, 11.6)	7.9 (4.96, 12.0)	8.1(5.6, 11.5)	8.2 (5.8, 12.1)	36.9 (24.34 45.6)	38 (24.5, 48.8)	40.2 (34.6, 47.7)	41.6(34.5, 47.5)
Zinc (mg)	Mean (SD)	3.50 (2.45)	3.44 (2.63)	3.57(2.42)	3.62(2.72)	15.1(6.6)	14.2 (6.5)	16.5 (4.3)	15.6 (3.95)
	Median (25th, 75th)	3.04 (1.85, 4.69)	3.03 (1.77, 4.43)	3.08 (2.14, 4.48)	3.05 (2.19, 4.43)	15.1(9.7, 19.4)	14.4 (9.2, 17.9)	16.2 (13.7, 19.2)	16(13.1, 17.9)
Vitamin A (µg RE)	Mean (SD)	298 (255)	99.2(98.3)	380 (395)	147 (187)	486 (413)	228 (327)	675 (676)	331 (475)
	Median (25th, 75th)	266 (130, 395)	81.2 (30.7, 152)	255(76.6, 563)	95.7(30.8, 185)	377 (234, 571)	154 (87, 238)	525(185, 887)	195 (77.8, 348)
Calcium (mg)	Mean (SD)	81.0 (61.0)	88.1 (74.5)	84.5 (64.2)	91.1 (72.1)	322(148)	355 (191)	330 (105)	341(118)
	Median (25th, 75th)	66.0 (41.0, 110.0)	66.8 (43.9, 117)	69.1 (47.3, 101.7)	72.3 (47.3, 110)	312(200, 412)	336 (204, 459)	323 (270, 380)	324 (270, 387)
Mg (mg)	Mean (SD)	132 (83.3)	154 (122)	144.5(104.6)	161.8(125)	605(226)	660(270)	708(175)	724 (178)
	Median (25th, 75th)	120 (74.1, 175)	132 (83.5, 209.5)	121.5(86.4, 178.8)	134(90.0, 197)	612 (431, 748)	670 (443, 837)	705 (608, 827)	743 (618, 838)
Vitamin B1 (mg)	Mean (SD)	0.39 (0.26)	0.42 (0.33)	0.42(0.28)	0.44(0.33)	1.75(0.73)	1.77 (0.77)	1.89 (0.47)	1.88 (0.47)
	Median (25th, 75th)	0.36 (0.21, 0.54)	0.36 (0.21, 0.55)	0.37(0.25, 0.52)	0.37(0.26, 0.52)	1.75(1.14, 2.23)	1.77 (1.14, 2.28)	1.89(1.61, 2.23)	1.92(1.58, 2.19)
Niacin (mg)	Mean (SD)	3.12 (1.97)	3.21 (2.44)	3.32(2.34)	3.45(2.79)	14.8 (5.3)	13.9 (5.3)	17.3 (4.64)	16.1 (4.2)
	Median (25th, 75th)	2.90 (1.72, 4.11)	2.81 (1.78, 4.33)	2.80(1.99, 4.14)	2.93(2.00, 4.14)	14.9 (11.0, 18.3)	13.9 (9.9, 17.6)	16.8(14.5, 19.6)	16.2 (13.5, 18.3)
Vitamin B6 (mg)	Mean (SD)	0.15 (0.14)	0.19 (0.22)	0.17(0.19)	0.21(0.23)	0.75(0.54)	0.89 (0.60)	0.82 (0.64)	0.87(0.62)
	Median (25th, 75th)	0.11 (0.05, 0.18)	0.13 (0.06, 0.26)	0.12(0.07, 0.20)	0.14(0.08, 0.27)	0.62(0.40, 0.93)	0.75 (0.43, 1.19)	0.62(0.37, 1.02)	0.69(0.45, 1.07)
Vitamin B12 (µg)	Mean (SD)	0.19 (1.71)	0.10 (0.20)	0.12(0.24)	0.11(0.23)	0.01(0.50)	0.01(0.48)	0.09 (0.41)	0.07(0.26)
	Median (25th, 75th)	0.00(0.00, 0.00)	0.00(0.00, 0.00)	0.00(0.00, 0.19)	0.00(0.00, 0.03)	0.00(0.00, 0.00)	0.00(0.00, 0.00)	0.00(0.00, 0.00)	0.00(0.00, 0.00)
Pentatonic acid (mg)	Mean (SD)	1.16 (1.81)	0.91 (0.67)	1.12(0.73)	0.98(0.70)	4.05 (2.00)	3.34 (1.52)	3.91 (1.12)	3.49 (0.91)
	Median (25th, 75th)	0.90 (0.57, 1.42)	0.79 (0.47, 1.22)	1.01(0.63, 1.44)	0.85(0.54, 1.24)	3.86 (2.40, 5.41)	3.33 (2.16, 4.23)	3.87 (3.18, 4.62)	3.49 (2.91, 4.01)
Vitamin C (mg)	Mean (SD)	11.9 (12.5)	11.2 (11.9)	13.9(13.2)	12.98(12.81)	47.7 (28.4)	65.7 (34.4)	48.2 (23.5)	64.0 (29.1)
	Median (25th, 75th)	6.1 (2.87, 20.8)	6.9 (2.87, 16.8)	8.4(3.58, 23.1)	9.9(3.35, 17.7)	41.73(29.64, 58.64)	60.5 (44.0, 83.8)	41.3(32.7, 57.7)	61.3 (42.2, 81.5)
Vitamin D (µg)	Mean (SD)	0.34 (1.48)	0.20 (0.39)	0.24 (0.47)	0.25 (0.48)	0.01(0.11)	0.03 (0.10)	0.03(0.19)	0.06(0.19)
	Median (25th, 75th)	0.00 (0.00, 0.00)	0.02 (0.00, 0.04)	0.00 (0.00, 0.19)	0.02(0.01, 0.09)	0.00(0.00, 0.00)	0.02(0.01, 0.03)	0.00(0.00, 0.00)	0.02(0.01, 0.05)

The estimated need for the 12-23-months old breastfed children from the complementary foods considering the average breast milk intake was adapted [13–15]. The estimated need of energy, protein, calcium, iron, zinc, vitamin B1, vitamin C and vitamin A were 548kcal, 5g, 346mg, 11.4mg (low bioavailability), 7.6mg (low bioavailability), 0.38mg, 5.18mg, 8mg and 126 retinol equivalent (µg RE), respectively for the 12-23-months old breastfeeding children. For the lactating women, the recommended nutrient intake (RNI): energy (2650kcal), protein (55g), calcium (100mg), iron (30mg for low bioavailability), zinc (17mg low for bioavailability), vitamin B1 (1.5mg), niacin (17mg), vitamin C (70mg) and vitamin A (850 µg RE) [16–18].

Inadequate intakes of many nutrients and energy (n=10) were prevalent (>50%) for the 12-23-months-old children in fasting and non-fasting periods, except for protein iron, magnesium and vitamin B1. Inadequate intake of vitamin A, calcium, vitamin D, vitamin C (only for results calculated by NS) vitamin B12, vitamin B6 and pantatonic acid was also prevalent (>50%) in lactating mothers. Beside these, the prevalence of inadequate intakes of vitamin B1, protein and iron for the 12-23-months-old children and energy, zinc and niacin intake for lactating mothers during fasting were between 30-69%, but these decreased during the non-fasting period, except the vitamin C for lactating mothers. The prevalence of low intake of magnesium for the 12-23-months-old children and protein, iron, magnesium and vitamin B1 for the lactating mothers were less than 30%. These also declined in non-fasting compared to fasting periods, regardless of the software used for identification of the inadequacy (Table 4.4).

Table 4.4 Number and percentage of 12-23 months old children and lactating women below the threshold of inadequate intake (<2/3 RNI)

	Children (12-23months)				Lactating women			
	Fasting period (n=377)		Non-fasting period (n=404)		Fasting period (n=568)		Non-fasting period (n=518)	
Nutrient	**CIMI n (%)**	**NS n (%)**	**CIMI n (%)**	**NS n (%)**	**CIMI n (%)**	**NS n (%)**	**CIMI n (%)**	**NS n (%)**
Energy (kcal)	273 (72.4)	272(72.1)	289 (71.5)	270 (66.8)	248 (43.7)	242 (42.6)	134 (25.9)	114 (22.0)
Protein (g)	120 (31.8)	114(30.2)	90 (22.3)	92(22.8)	146 (25.7)	151 (26.6)	32 (6.2)	27 (5.2)
Iron (mg)	180 (47.7)	191 (50.7)	180 (44.6)	193 (47.8)	96 (16.9)	93 (16.4)	0 (0.00)	0 (0.00)
Zinc (mg)	324 (85.9)	323(85.7)	352 (87.1)	348 (86.1)	197 (34.7)	179 (31.5)	71 (13.7)	53(10.2)
Vitamin A (µg RE)	363 (96.3)	188 (49.9)	340 (84.2)	207(51.2)	544 (95.8)	424 (74.6)	445 (85.9)	277 (53.7)
Calcium (mg)	368 (97.6)	375 (99.5)	399 (98.8)	402(99.5)	526 (92.6)	562 (98.9)	509 (98.3)	515 (99.4)
Magnesium (mg)	41 (10.9)	39 (10.3)	24 (5.9)	33(8.2)	9 (1.60)	9(1.60)	1 (0.20)	0 (0.00)
Vitamin B1 (mg)	170 (45.1)	165 (43.8)	163 (40.3)	177(43.8)	120 (21.1)	105 (18.5)	1 (0.20)	15 (2.9)
Niacin (mg)	274 (72.7)	274 (72.7)	252 (62.4)	257 (63.6)	187 (32.9)	152 (26.8)	63 (12.2)	35(6.8)
Vitamin B6 (mg)	309 (82.0)	338 (89.7)	374 (92.6)	381 (94.3)	460 (81.0)	493 (86.8)	432 (83.4)	435 (84.0)
Vitamin B12 (µg)	365 (96.8)	360 (95.5)	381 (94.3)	379 (93.8)	568 (100.0)	568 (100)	511 (98.6)	507 (97.9)
Pantatonic acid (mg)	295 (78.2)	271 (71.9)	340 (84.2)	308 (76.2)	467 (82.2)	364 (64.1)	477 (92.1)	398 (76.8)
Vitamin C (mg)	318 (84.4)	277 (73.5)	317 (78.5)	268 (66.3)	160 (28.2)	331 (58.3)	153 (29.5)	309 (59.7)
Vitamin D (µg)	377 (100)	372 (98.7)	404 (100)	404 (100)	568 (100)	568 (100)	518 (100)	518 (100)

NB: The inadequacy of the 12-23-months old children and lactating women was declared as the energy, protein and other micronutrients intake was below two-third of the recommended nutrient intake (RNI). For the zinc and iron, the RNI for CIMI was set based on the individual consumption pattern and category of bioavailability, otherwise for the NS, the low and 5% bioavailability of zinc and iron was used in this study, respectively. The RNI for the 12-23-months old breastfed children was energy (950kcal (male), 850kcal (female)), protein (13.5g), calcium (500mg), iron (11.6mg), zinc (8.3mg), vitamin B1 (0.5mg), niacin (6mg), vitamin B6 (0.5mg), vitamin C (30mg), pantothenic acid (2mg), vitamin B12 (0.9 µg), vitamin A (400 µg), vitamin D (5 µg) and magnesium (60mg). For the lactating mothers, the recommended nutrient intake (RNI): energy (2650kcal), protein (55g), calcium (1000mg), iron (30mg and 15mg for very low and low bioavailability, respectively), zinc (17mg low for bioavailability), vitamin B1 (1.5mg), niacin (17mg), vitamin C (70mg), vitamin A (850RAE), vitamin B6 (2mg), pentatonic acid (7mg), vitamin B12 (2.8 µg), vitamin D (5 µg) and magnesium (270mg) [16–18].

Table 4.5 Average mean differences of calculated nutrient intake by CIMI and NS. Categorization of accuracy was performed according percentage of mean difference in relation to mean NS result

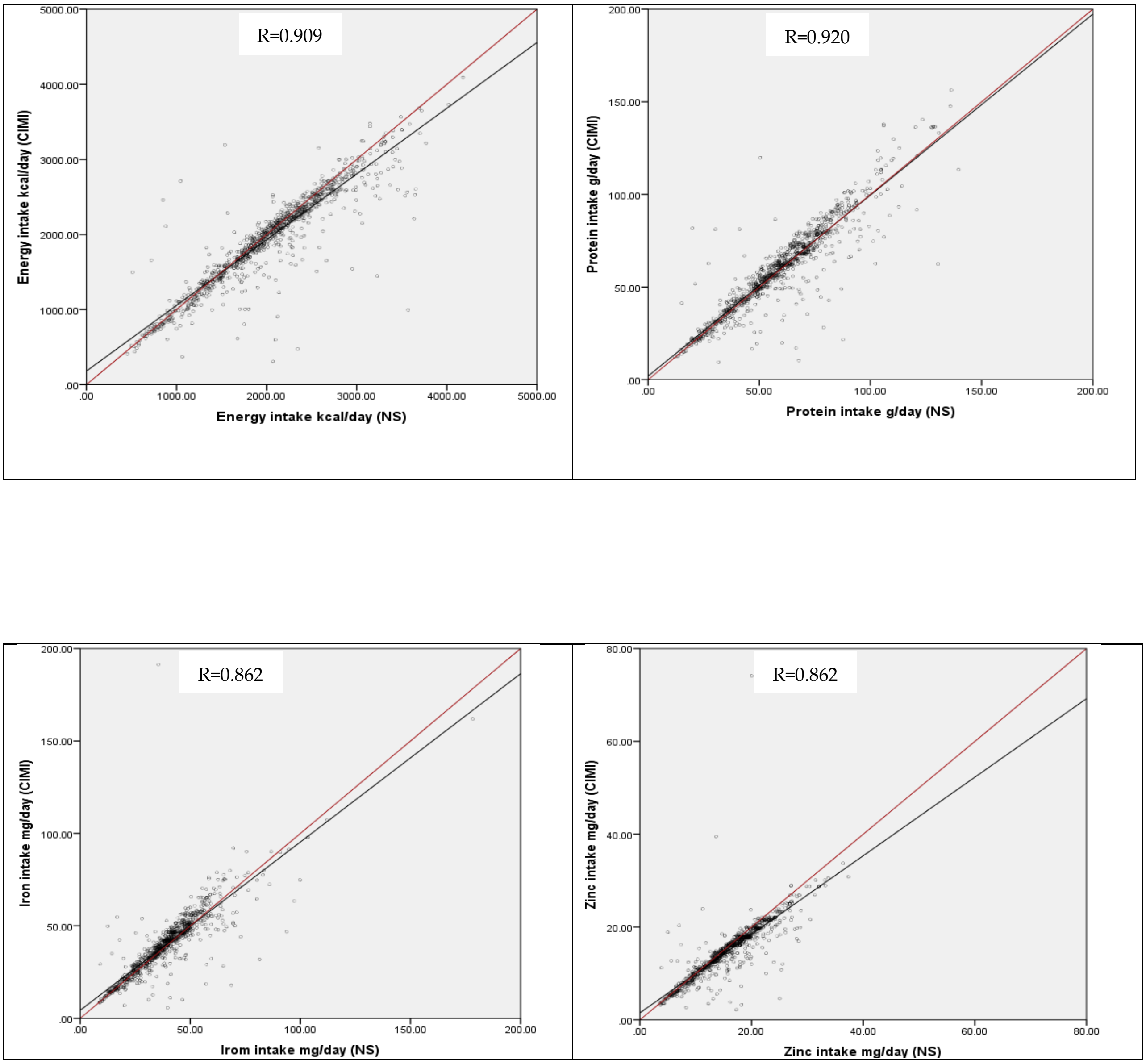
Nutrient	Children (12-23months) (n=781)			Lactating women (n=1086)		
	Mean difference between CIMI and NS result (±SD)	**Mean difference in % of mean nutrient intake calculated by NS**	**Accuracy category**	**Mean difference between CIMI and NS result (±SD)**	**Mean difference in % of mean nutrient intake calculated by NS**	**Accuracy category**
Energy (kcal)	4.15 (186.23)	1.06	Very high accurate	59.05 (273.33)	1.91	Very high accurate
Protein (g)	-0.71 (5.68)	-3.49	Very high accurate	-0.60 (8.99)	-1.71	Very high accurate
Iron (mg)	-0.82 (4.31)	-9.48	Good accurate	-0.85 (8.05)	-3.42	Very high accurate
Zinc (mg)	0.01 (1.71)	-4.09	Very high accurate	0.92 (2.91)	4.44	Very high accurate
Vitamin A (µg RE)	213.31 (202.21)	-22.90	Moderate accurate	301.01 (353.64)	24.51	Moderate accurate
Calcium (mg)	-6.75 (43.06)	-8.74	Good accurate	-22.46 (83.27)	-7.08	Good accurate
Magnesium (mg)	-19.66 (73.37)	-16.16	Moderate accurate	-36.02 (117.26)	-6.50	Good accurate
Vitamin B1 (mg)	-0.02 (0.17)	-6.34	Good accurate	0.00 (0.27)	-0.96	Very high accurate
Niacin(mg)	-0.12 (1.57)	-5.31	Good accurate	1.05 (2.48)	5.74	Good accurate
Vitamin B6 (mg)	-0.04 (0.14)	-36.08	Low accurate	-0.10 (0.31)	-21.28	Moderate accurate
Vitamin B12 (µg)	0.01 (0.17)	-	-	0.01 (0.15)	-	-
Pentatonic acid (mg)	0.15 (0.40)	10.77	Good accurate	0.57 (0.85)	11.23	Good accurate
Vitamin C (mg)	0.82 (8.03)	-8.04	Good accurate	-16.95 (19.09)	-42.06	Low accurate
Vitamin D (µg)	0.00 (0.13)	-	-	-0.03 (0.09)	-	-

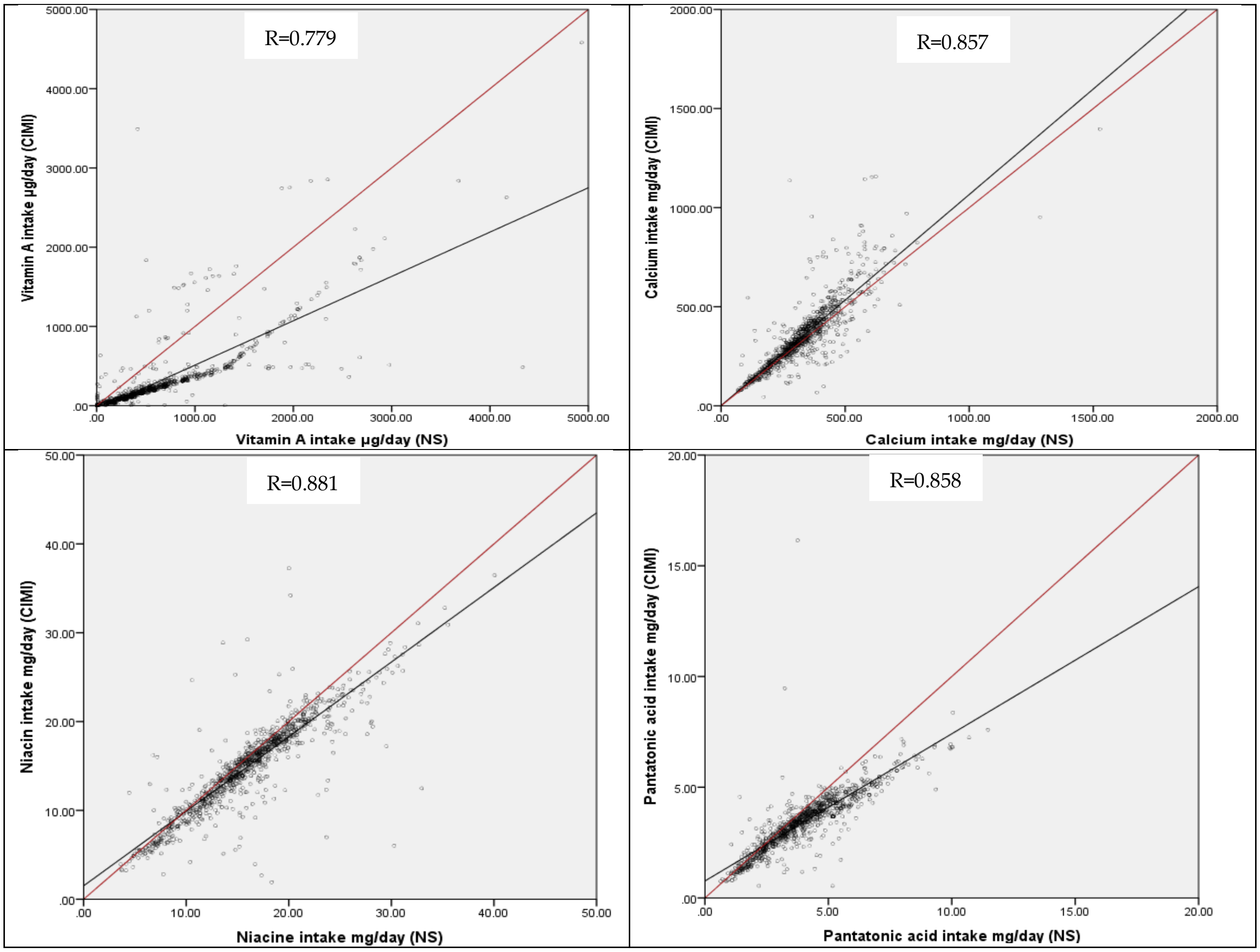
NB: Nutrients with a very high accuracy (difference expressed as % of NS result: +/-0<5%), good accuracy (+/-5-15%), moderate accuracy (+/-15-30%) and low accuracy (+/->30%), this is adopted from Lambert et al., 2018. For vitamin B12 and vitamin D, the mean difference % was not calculated, as most of these values were zero in NS, which is a denominator for computation.

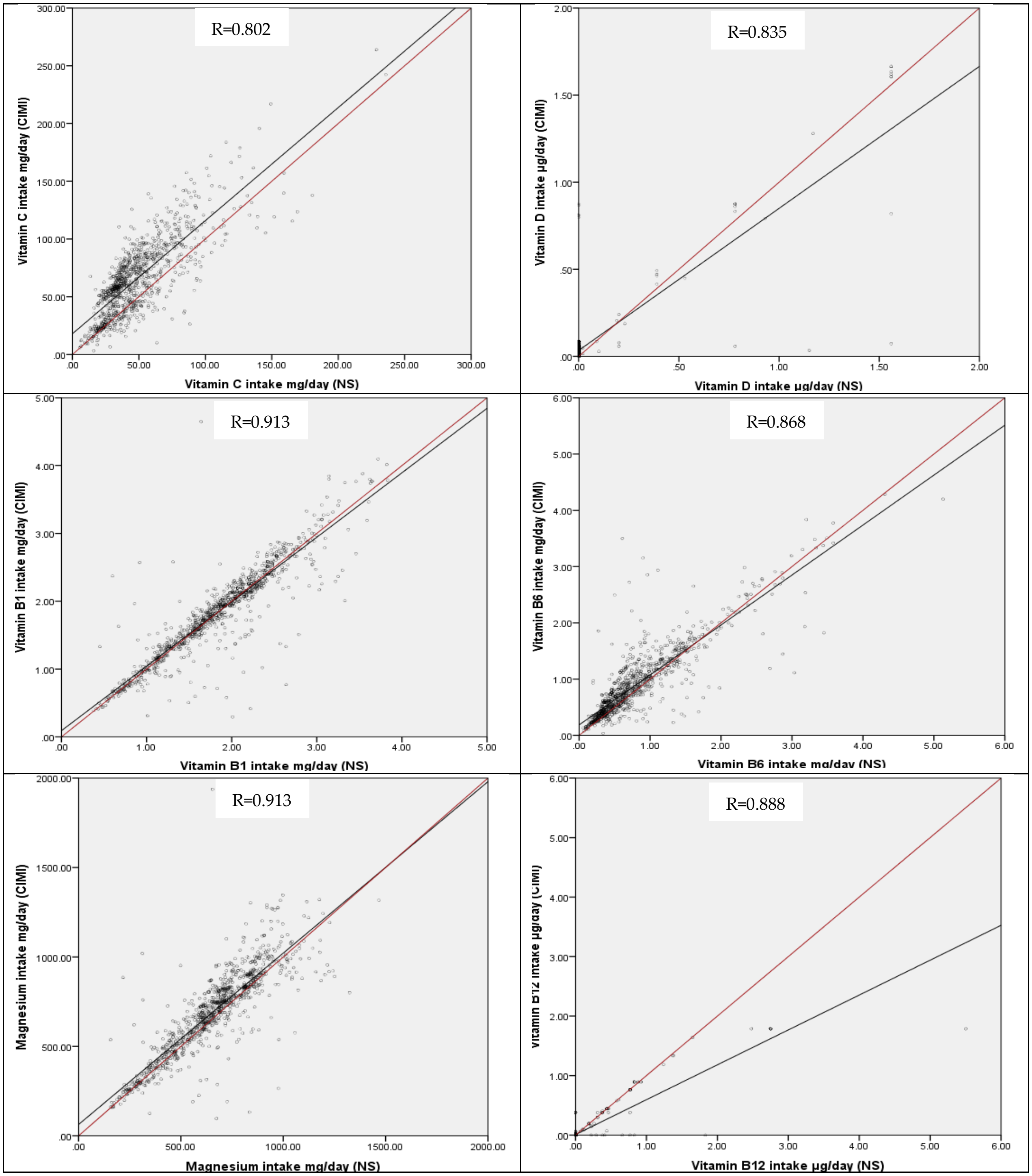
Among the mean differences of CIMI from NS calculated for each nutrient intake, the highest variation was observed in vitamin A, both for children and mothers, whereas the lowest was observed in vitamin D and vitamin B1 for children and mothers, respectively. However, the % of mean difference using the actual average nutrient intake in terms of NS was highest in vitamin B6 for children and vitamin C for mothers. The lowest was observed in the energy and vitamin B1 for children and mothers, respectively. According to Lambert and colleagues' criteria for categorizing the precision of CIMI in terms of NS, the results of energy, protein, iron, zinc, calcium, vitamin B1, niacin and pentatonic acid were either very high or accurate. Whereas, low precision was observed in vitamin B6 for the 12-23-months-old children and vitamin C for the lactating mothers (Table 4.5).

Beside these, the highest correlation coefficient (R) between CIMI and NS was observed in vitamin D (0.956) and protein (0.920) for the 12-23-month-old children's and lactating women, respectively. But, the lowest was observed in vitamin B12 (0.741) for the 12-23-month-old children and vitamin A (0.779) for the lactating mothers (Figures 4.1 and 4.2). All correlations were highly significant ($P<0.001$).

Fig. 4.1 Correlation of energy and nutrient intake of Ethiopian women calculated by NS and CIMI

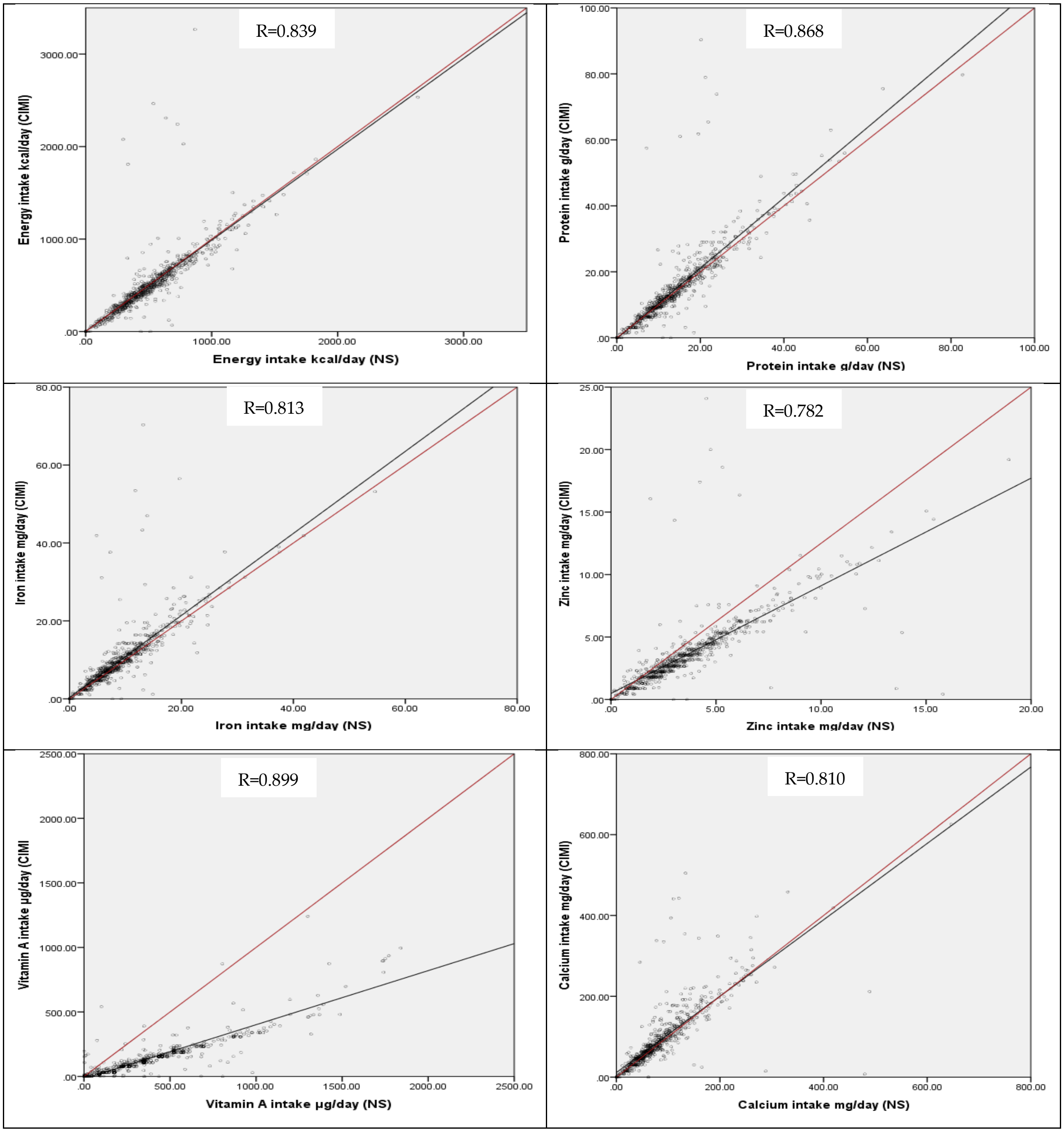


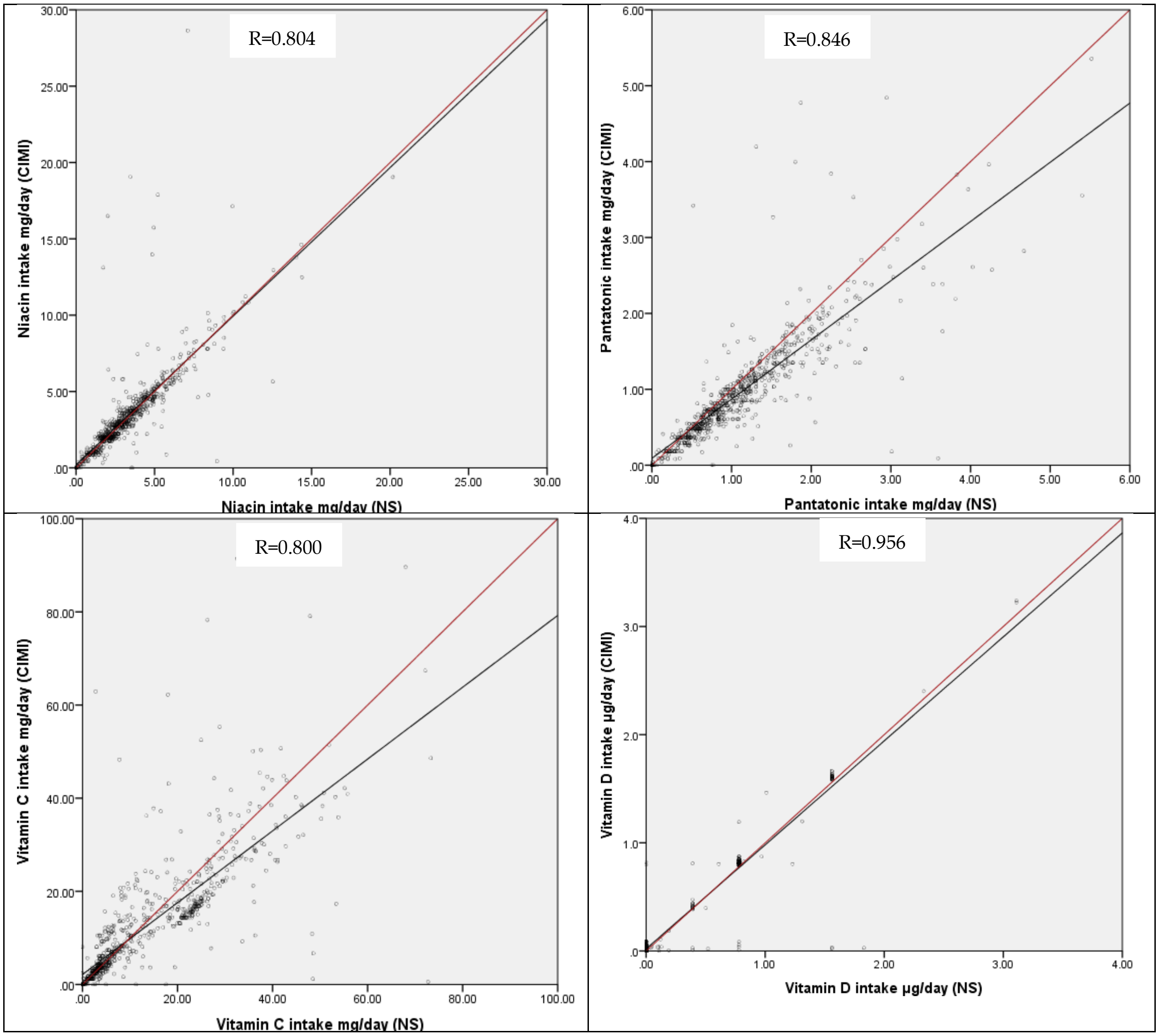

R=0.779
Vitamin A intake µg/day (CIMI)
Vitamin A intake µg/day (NS)
.00
1000.00
2000.00
3000.00
4000.00
5000.00
R=0.857
Calcium intake mg/day (CIMI)
Calcium intake mg/day (NS)
.00
500.00
1000.00
1500.00
2000.00
R=0.881
Niacin intake mg/day (CIMI)
Niacine intake mg/day (NS)
.00
10.00
20.00
30.00
40.00
50.00
R=0.858
Pantatonic acid intake mg/day (CIMI)
Pantatonic acid intake mg/day (NS)
.00
5.00
10.00
15.00
20.00

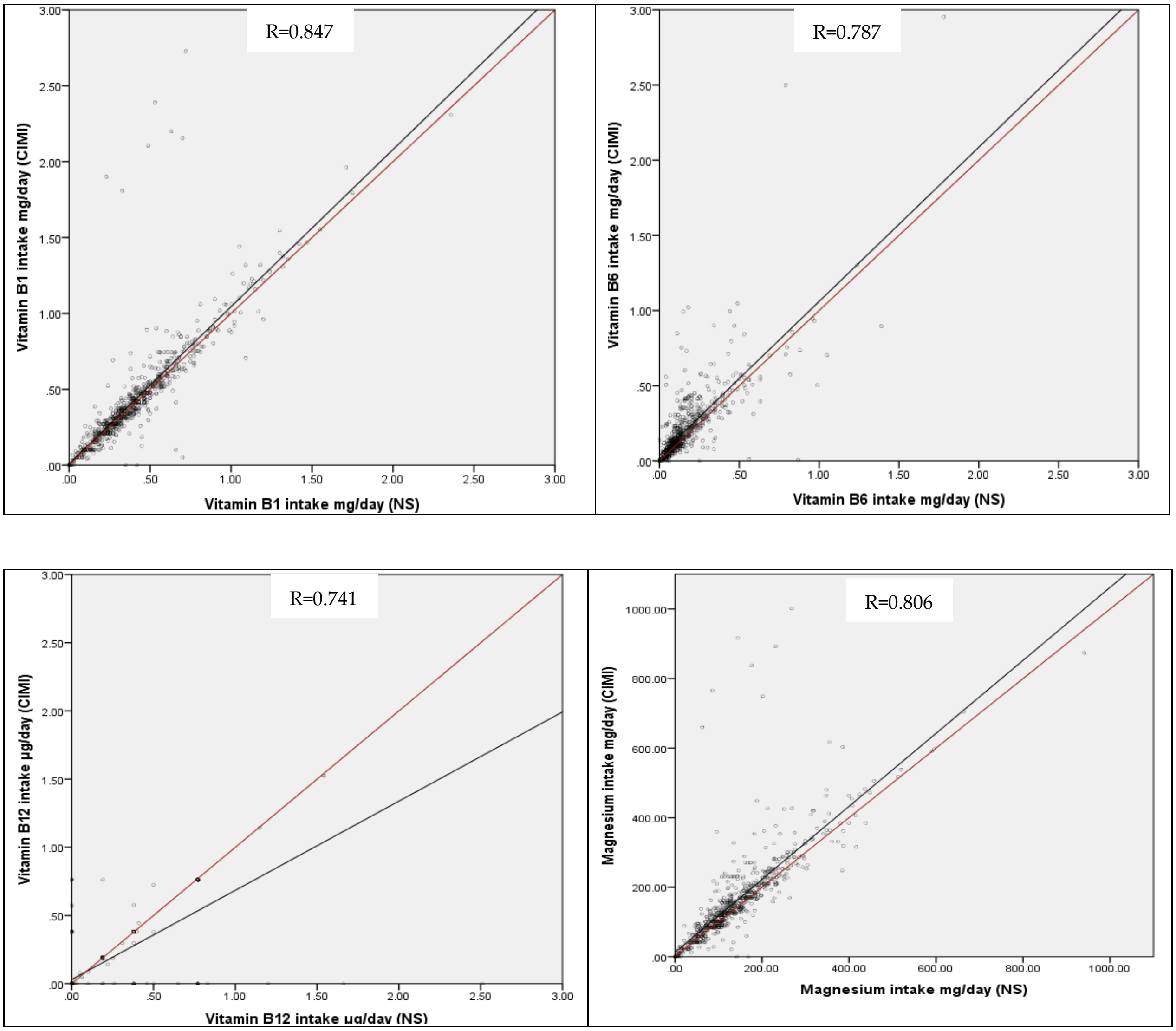


NB: The red line in these scatter plots is the reference line (y=x; R=1), which means the results produced from the two programs are identical. The black line represents the regression line of the data pairs calculated by CIMI and NS.

Fig. 4.2 Correlation of energy and nutrient intake in between NS and CIMI in 12-23 months old children, Ethiopia




R=0.804
Niacin intake mg/day (CIMI)
Niacin intake mg/day (NS)
R=0.846
Pantatonic intake mg/day (CIMI)
Pantatonic intake mg/day (NS)
R=0.800
Vitamin C intake mg/day (CIMI)
Vitamin C intake mg/day (NS)
R=0.956
Vitamin D intake µg/day (CIMI)
Vitamin D intake µg/day (NS)



NB: The red line in these scatter plots is the reference line (y=x; R=1), which means the results produced from the two programs are identical. The black line represents the regression line of the data pairs calculated by CIMI and NS.

4.4. Discussion

To the best of our knowledge, this is the first study in Ethiopia, which focuses on a) adaptation and validation of a simple and rapid web-based dietary nutrient intake assessment tool for Ethiopian population, b) assessment of dietary nutrient and energy intakes of the 12-23-months-old children and their lactating mothers during religious fasting and non-fasting periods in Northern Ethiopia.

4.4.1. Validation of Calculator for Inadequate Micronutrient Intake (CIMI)

For the first time, CIMI was developed in Indonesia for the Indonesian population [10]. The CIMI software presented in this study is the second next to Indonesia, which is developed for Ethiopian population, using commonly consumed Ethiopian foods. Like CIMI developed in Indonesia, we used the food group approach which considered the amount of food consumed per capita per day, the nutrient composition of the food items specially the micronutrients that are of public health importance in Ethiopia (vitamin A, Fe, and Zn) and standard food grouping (e.g.:- vegetable to vegetable) [9,19–22]. Shape and volume of food items, local utensils or food size or volume used in local market as standardized local units and varietal differences were included to create the 31 food groups. For example, chard, lettuce and Ethiopian kale were under 'green leaves' food group based on their micronutrient contents (Fe, Zn and vitamin A), shape and because of being vegetables. Likewise, sweet potato, potato, taro, cassava, yam, *amicho* (boiled decorticated root part of false banana) and anchote (*Coccinia abysinica)* are aggregated based on their shape and natural group into 'potato and related foods' group. Maize and teff are grouped into two groups each as white and yellow, and white and red, because these grains are highly consumed by majority of Ethiopians and based on their pro-vitamin A and Fe contents, respectively [11]. Beside this, assessment of food amounts a slider with 15 intervals, which considered the minimum and maximum amount estimated to be eaten by the young children and adult was also considered.

Accordingly, the average intake of most nutrients and energy calculated by CIMI and NS were nearly similar, except for vitamin A, in both the children and lactating women, and vitamin C in the lactating women, regardless of the periods. Our vitamin A result is in line with previous CIMI study in Indonesia [10]. The possible explanation for variable vitamin A intake estimation by CIMI in our case was, the average vitamin A content of the butter and oil food group was lower than the palm oil, which is one of the item created this group, but was available by the cooperative enterprises in the present study area and consumed during the fasting and non-fasting surveys. The availability of different oil types at different time in the country depends on the massive import oil types by the subsidy of the Ethiopian government. Therefore, deselecting the unconsumed oil type from this food group will be an important activity for future CIMI use. The reason for the high vitamin C values of CIMI for the lactating women was due to the great share (43.8%) of the tomato for the ‘other vegetables` group, but less consumed compared to the cabbage, which has relatively lower vitamin C increased the average vitamin C content of the ‘other vegetables` group.

Protein, iron, calcium, magnesium, vitamin B1, and B6 intake estimated by CIMI were slightly higher than NS, in both the study groups. The reason for the high CIMI of protein, iron and calcium could be due to the consumption of high amount of peas, although peas’ contribution to the relevant food group is only 12.4%, which does not represent the real share of peas in this group. Peas have got a lower content of these nutrients compared to most food items in the group. Beside this, the intervals to set up the amount with the slider get larger if the consumption is increasing in most of the food groups in CIMI. Therefore, the selection of the slider either below or above the estimated amount of the food group will depend on the nearest amount set up in the sliders. So if the amount approaches to the upper slider, then automatically the upper slider will be selected and these will lead to overestimation of intake of specific nutrients when compared to NS. The later could also work for magnesium and vitamin B1 in pepper and egg food groups, respectively. Ethiopian kale, which has got a higher vitamin B6 content than other vegetables in the 'green leaves' food group, contributed 58.4% for this group. But Ethiopian kale was less consumed in the study area and this leads to an overestimation of vitamin B6 intake in CIMI.

The number (percentage) of participants identified as inadequate in nutrients (<2/3 RNI) by CIMI and NS were similar in most nutrients considered, except for vitamin A for 12-23-months-old children and lactating women, and vitamin C only for the lactating women, regardless of the study period. These could be due to the high and low average values of the vitamin A and vitamin C in the 'butter and oil`, and 'other vegetable groups` for individuals than the values in NS, respectively.

According to Lambert et al. (2018), vitamin A was moderately calculated by CIMI for the 12-23-months-old children and lactating women. The reason mentioned earlier for variation in the average values of vitamin A produced by CIMI and NS, leads to higher mean % difference, which is the criteria for this classification. Likewise, CIMI calculated the vitamin B6 intake with low and moderate precisions for the 12-23-months-old children and lactating women, respectively. The possible reason could be the small mean vitamin B6 differences between CIMI and NS in few individuals that increased their mean difference (%) dramatically (Table 4.5). The moderate precision of magnesium in the 12-23-months-old children might be related with the average CIMI of the group which was higher than the commonly consumed pea entered in NS.

The low precision in the vitamin C variation could be due to the average vitamin C value of the ‘other vegetables’ group, which was relatively high because of tomato. Strong correlations between CIMI and NS were found in all the nutrients and energy for both study groups (Figure 4.1 and 4.2). The correlation coefficients between CIMI and NS of protein, iron, zinc and vitamin A for the 12-23-months-old children and energy, protein, iron and zinc for lactating mothers were higher compared with the previous study in Indonesian population [10]. This could be attributed to the smaller sample size in the Indonesian study. Furthermore, the correlation coefficients of most nutrients in our study were higher than validation results of CIMI in Tanzania women, except for energy [12]. In general, our validation study confirmed that CIMI developed for rural Ethiopian population with commonly consumed Ethiopian foods calculates the average nutrient intake accurately. Additionally, it identifies the inadequate micronutrient intake of individuals using FAO/WHO recommendation for nutrient intake (RNI). Unlike other dietary assessment techniques, CIMI provides result immediately after the interview is completed, which enables the enumerator to provide immediate feedback to the interviewee and suggest dietary improvements considering the socio-economic status of the household, culture of the society, availability of potential and alternative food items in local farms and/or market. Currently, most of the dietary assessment and intervention studies use diet diversity scores, a proxy indicator for assessing the dietary quality at household and individual levels [23]. However, this technique only focus on the assessment of diversity of food groups consumed, because the smaller amount of intake from the food groups will challenge the validity of the diet diversity score result, as a proxy indicator for micronutrient adequacy of an individual. To overcome this problem, many studies have used a cutoff of ≥15 g to count the food group as consumed in women in reproductive age [23]. But, still the controversy remains on how quantification is practical in real qualitative diet diversity assessment technique, unless the diet diversity data is extracted from other quantitative dietary intake data. Thus, CIMI can replace the qualitative diet diversity, by producing much more results on the diet quality of an individual, and overcoming the challenges encountered by DDS. CIMI can also be used in cross-sectional and/or longitudinal/ intervention studies, in situation where the conventional diet diversity score is not appropriate or requires the quantitative dietary assessment methods. These indicate that CIMI developed for Ethiopian population is applicable for dietary micronutrient assessment at individual level in rural setting. The accumulation of this individual data can provide information on dietary nutrient intake at population level for designing targeted micronutrient prevention and intervention activities. In general, CIMI can be an important tool for nutrition and related researchers, practitioners, policy makers and planners in Ethiopia.

4.4.2. Dietary Nutrient Intakes of 12-23-months-old Children and Lactating Women in Rural Ethiopia

The median intake of energy, iron, zinc, thiamin, niacin and calcium in this study were below the estimated need from complementary food for the 12-23-months-old breastfeeding children, regardless of the study periods. But, the median intake of dietary protein, and vitamin C (only during non-fasting period) met their needs. These results are in line with previous studies in different parts of Ethiopia [13,24–26]. The vitamin A intake of the 12-23-months children in the present study was also above the estimated need and higher than its median intake in the 6-35-months-old children of Tigray region and other findings, elsewhere in Ethiopia [13,24–27]. This could be due to the consumption of palm oil fortified with vitamin A for preparation of complementary food as noticed during the survey periods. Furthermore, the prevalence of inadequate dietary intakes (<2/3 RNI) of zinc was very high (>75%) in the 12-23-months-old children, followed by vitamin C, energy and niacin (51-75%), and protein, iron, vitamin A and vitamin B1 (20-50%), respectively. But, the prevalence of low intake of energy, protein, niacin and vitamin C were decreased during non-fasting compared to fasting period. The finding of recent investigation in the same study area evidenced that the prevalence of 6-23-months-old children who fulfilled the minimum acceptable diet (MAD) criteria was 2.3% during fasting and 6.7% during non-fasting period. A study in *Libo Kemkem* and *Fogera* districts in Ethiopia showed that zinc and vitamin A deficiencies were prevalent in the school-age children [28]. Furthermore, a recent national study in Ethiopia revealed that the average dietary zinc intake of 6-35-months-old children from Tigray region and at national level were low [22]. A study conducted in four African countries including Ethiopia also revealed that anemia, vitamin A and zinc deficiencies are of public health concern in these countries [29].

In the present study, the median intake of energy, protein, vitamin A, calcium, vitamin C and niacin (fasting period only) were below the recommended nutrient intake (RNI) for lactating mothers, but not for iron, zinc and vitamin B1. Except for iron, the intake of energy, protein, zinc and vitamin A were very close to the values for Tigray region and national average [27]. Our findings on iron and calcium intake were higher than earlier studies on lactating and pregnant women in Northern part of Ethiopia [30,31]. These might be due to the fact that food taboos may be related to a reduction of food intake by mothers during pregnancy. Main reasons for food taboos are fear of obstetric complications associated with the delivery of a bigger baby, plastering on the fetal head, fear of abortion, evil eye and fetal abnormality [32–34]. The prevalence of inadequate dietary intake of vitamin A and vitamin C was higher, followed by energy, zinc, niacin, vitamin B1 and iron. Previous studies in Ethiopian children and women confirmed that the prevalence of iron, zinc and vitamin A deficiencies was high using blood biomarkers [35–40]. Except for calcium and vitamin C, the inadequacies were decreased after the two months lent fasting periods. Therefore, considering the continuously high prevalence of inadequate intake of vitamin C in both study groups lead to the assumption that consumption of vitamin C rich foods are chronically low in the study area. Therefore, the deficiency of these micronutrients is expected to be higher in our study district and further studies using biomarkers should be done. The possible explanation for this might be related with the low consumption of fruits, animal source foods including dairy products, root crops like potato, anchote in the study area [1,2]. Surprisingly, almost all the 12-23-months-old children and lactating mothers did not take vitamin B12, vitamin D and calcium. Previous national study in Ethiopia found that only 15.1% of non-pregnant women were deficient in vitamin B12 using blood biomarker [35]. The big difference from our finding could be related to the method of assessment where the serum total vitamin B12 was used as biomarker, which gives less information in identifying vitamin B12 deficiency [41,42]. Therefore, urgent investigation on the deficiency of vitamin B12 should consider the biomarker like methyl malonic acid or Holotranscobalamin in urine and blood samples, to understand the situation in the study area more precisely[42,43]. Likewise, earlier study in Ethiopian non-pregnant women showed that there was no participant that ever consumed vitamin D–rich foods, fortified foods, or dietary supplements, and as a result Vitamin D insufficiency is a serious problem, even though Ethiopia is located near the Equator [44]. Highest prevalence of inadequate intake of calcium was also found in studies conducted in

Gondar (90.4%), Butajira (99%) districts, and at national (89-96%) level [30,45,46]. Therefore, the proposed universal calcium supplementation in Ethiopia should be implemented [46]. Therefore, nutrition sensitive agriculture in both plant and livestock production should be promoted and implemented in sustainable manner.

Previous studies in the same study population and study area evidenced that the dietary diversity score were low in general, lower in the lent fasting compared to non-fasting period, both in the lactating mothers and their 6-23-months-old children [1,2]. In line with this, our present study confirmed that dietary nutrient intake (DNI) is lower in lent fasting compared to non-fasting period, both in the young children and lactating women. These indicate that, dietary nutrient intake in the district was sub-optimal, which might be one of the multi-faceted cause for the highest prevalence of maternal and child undernutrition in the study district, Tigray region and Ethiopia at large (Table 4.2).

Our present study has many strengths. Among these, the average DNI of the young children and women and the prevalence of inadequate intake of most important nutrients were addressed with a large sample size in rural Ethiopia. The longitudinal study design considered the longest religious fasting period among the seven official Ethiopian Orthodox fasting periods, whereas the non-fasting period was the fifty days after the fasting period. For the first time in Ethiopia, dietary assessment software is developed using commonly consumed foods in rural Ethiopia. Additionally, the validity of this software was assessed using groups (children and women) vulnerable for malnutrition in religious fasting/non-fasting periods. However, only one 24-hr dietary recall was used for this assessment, and the study was conducted in only one administrative region in Ethiopia, out of the eleven, are limitations of this study.

4. 5. Conclusions

Our study indicated that except protein and magnesium, the prevalence of inadequate intake (<2/3 RNI) of energy and most micronutrients was high in the 12-23-months-old children. Likewise, the prevalence of inadequate intake of vitamin A, calcium, vitamin B6, vitamin B12, pentatonic acid and vitamin C were also high in the lactating mothers. However, these high prevalences of inadequacy in energy and macro-and micronutrients in the 12-23-months-old children and lactating mothers were more affected during the lent fasting period. Therefore, the present nutrition intervention should give more attention on diet improvement activities of the children and women especially during religious fasting periods. Alarmingly, almost all the 12-23-months-old children and lactating mother's in the study area obtained below two-third of the RNI for vitamin B12, vitamin D and calcium from their diet. Therefore, urgent further investigation should be done for immediate public health nutrition intervention in the district, in addition to the implementation of the proposed universal calcium supplementation in Ethiopia. Our result also confirmed that CIMI developed for rural Ethiopian population estimates the average nutrient intake accurately. It also identifies inadequate micronutrient intake of individuals using FAO/WHO recommended nutrient intake (RNI) directly after the interview. This enables the enumerator to provide immediate nutrition education and suggest context based dietary improvements, unlike other dietary assessment techniques. CIMI can also replace the DDS, a qualitative dietary assessment tool, by overcoming the drawback, which is related with counting insignificant intake in the score and by producing more results. CIMI can also be used in cross-sectional and/or longitudinal/ intervention studies, in situation where the conventional diet diversity is not appropriate or requires the quantitative dietary assessment methods. Therefore, CIMI can be used for dietary assessment survey in Ethiopia.

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4.6. References

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Chapter 5

General discussion

5. General discussion

In this chapter, the core findings on the dietary pattern and undernutrition of lactating women (underweight) and 6-23-months-old children (underweight, wasting and stunting) in relation with the Ethiopian Orthodox lent fasting and non-fasting periods, considering the fasting status of lactating mothers are discussed. The factors associated with undernutrition of the lactating mothers and their breastfeeding 6-23-months-old children are also dealt. Furthermore, the trend on estimated dietary energy and macro- and micronutrients intake and the prevalence of inadequacy of the lactating mothers and their 12-23-months-old children between/during fasting and non-fasting periods are discussed. Moreover, the development of CIMI app and the validation of the results in comparison with an established nutrition assessment software called NutriSurvey are discussed. Finally, the conclusion of the whole study is also conferred.

5.1. Undernutrition in Lactating Women and their 6-23-Months-Old Children

5.1.1. Prevalence of undernutrition in lactating women and their 6-23-months-old children

In low and middle income countries, undernutrition in mothers and their children persists as an inescapable and devastating condition [1]. It is also the principal cause among the total morbidity, mortality and disability-adjusted-life-years. Maternal undernutrition is an independent factor of the nutritional status of their children. Earlier studies in different countries have shown that mothers who were short (<145 cm) and had low body mass index were linked with low birth weight (LBW) of their children, increased offspring mortality, underweight, stunting during the childhood, and these undernutrition problems appear later at the adulthood [2–5]. Likewise, studies elsewhere, in Ethiopia also confirmed that maternal undernutrition is associated with child birth outcome, stunting and underweight [6–9]. The reason for some of the cases could be, as the woman is shorter, then the storing of protein and energy is expected to reduce and have smaller size of reproductive organs and pelvis diameter. These, could limit the intra-uterine growth of the fetus, and later the growth of an infant by reducing the quantity and quality of breast milk, as a result a stunted child [10]. In the present study, the prevalence of short maternal height (< 145cm) was 1.4% (Chapter 2, Table 2.4), which was lower than previous findings in Tigray region and national average, in Ethiopia [11–13]. Similarly, the prevalence of underweight in the lactating mothers was 32.6-32.8% in the study area, which was lower than results reported in earlier studies in Ethiopia [13–15]. But, alarmingly, this prevalence was very high (51%) in fasting lactating mothers compared to the 25% prevalence in non-fasting mothers (Chapter 2, Table 2.4). The later finding was comparable with results of earlier studies in lactating mothers living in mid-land agro-ecology of North Ethiopia [15]. At the same time, the average body mass index (BMI) values of the fasting mothers was lower compared to non-fasting group, which is consistent with the findings of studies conducted on Greek Orthodox Christians [16]. This could be related to the decreased number of meals, resulting from lower calorie intake in fasting people compared to non-fasting during fasting days [10,17].

In addition to the very high prevalence of underweight in fasting mothers found in our study, the prevalence of wasting, underweight and stunting were 4.0-4.8%, 11.7-15.7% and 31.6-33.7% in the 6-23-months-old children of the study area (Chapter 3, Table 3.2). Our findings were lower than earlier findings for the Tigray region and national prevalence’s of the last Demographic and Health Survey (DHS) in Ethiopia. According to Ethiopian DHS (2016), the prevalence of stunting and underweight decreased from 58% and 41% in 2000 to 38% and 24%, with only 2% decrease in wasting in 16 years' interval, at national level, which was the aggregate for the regions including Tigray [13]. These trends in reduction of undernutrition indicated that nutritional status of Ethiopia children is improving, although the existing prevalence is unacceptably high. The present study also showed that the average z-scores of stunting (LAZ), underweight (WAZ) and wasting (WLZ) of the children of the fasting mothers were significantly lower compared to the non-fasting group (Chapter 3, Table 3.5). Additionally, the average z-scores of WAZ of children of both fasting and non-fasting mothers showed improvement in non-fasting period after the lent fasting period (Chapter 3, Table 3.6). These indicated that fasting affect the nutritional status of women at lactation, and it also impaired the nutritional status of their breastfeeding children. Furthermore, during the long fasting period, the nutritional status of the children was also affected, regardless of their mother fasting status.

5.1.2. Factors associated with undernutrition of lactating women and their 6-23-months-old children

Maternal and child undernutrition is the problem in the community caused by several factors of multi-dimensional nature. According to UNICEF conceptual framework of undernutrition, the immediate causes are inadequate intake and disease condition of an individual, whereas, the long term causes are household food insecurity, inadequate care, unhealthy household environment and lack of health services and shortage of income leading to poverty at the household and community level, and the basic causes for undernutrition are closely linked with social, political and economic basis of the society [1,18]. Accordingly, lots of efforts have been exerted in separate ways for long time, but the outcome was far below the global targets by most of the countries. As a result, fighting undernutrition shifted its focus from the narrow approach of undernutrition to multi-sectoral approach using multi-sectoral forces to synergize the efforts and accelerate the reduction of undernutrition in different countries and worldwide [19]. Therefore, nutrition is the core of the sustainable development goal (SDG), and it is a vital way for achieving the 12 SDGs out of the 17. Even, the remaining 5 also contribute for the improvement of nutrition worldwide [19]. In this regard, the government of Ethiopia has been doing a lot of activities using a multi-sectoral approach by integrating different national sector ministries. But, undernutrition as a public health problem still remains, due to inadequate commitment and lack of conducive structure in government system. As a result, the SEQOTA declaration, which needs a strong and high level commitment of government, with a goal of ending undernutrition by 2030, under the National Nutrition Program II was launched [19,20]. This goal is planned to be achieved through integrating community development in agriculture, health, nutrition, education, water, sanitation and hygiene and social protection activities [19]. However, our findings urged the involvement of religious institution in the implementation of multi-sectoral approach to accelerate reduction of undernutrition and achieve the goal set in 2030. For example, about one-third of lactating mothers included in our study fasted during their pregnancy and lactation periods (Chapter 2, Table 2.2), which is slightly lower than earlier finding (38%) in pregnant mothers of Shashemene district in Ethiopia [21]. Mothers who were fasting during their pregnancy and lactation periods in this study had 1.7 and 2.9 times more odds to be underweight than respective none fasting groups during the same periods, respectively (Chapter 2, Table 2.3). Likewise, children of fasted mothers during the pregnancy and lactation period were also more exposed to undernutrition (stunting, underweight, and wasting (only during lactation)) than those children whose mothers did not fast in the same periods (Chapter 3, Table 3.3). These show that fasting during pregnancy and lactation periods of the mothers affects, not only the nutritional status of mothers, but also the health and nutritional status of their fetus and/or breastfed child [10,22]. Earlier studies in sub-Saharan African including Ethiopia and Asian countries confirmed that younger mothers and children between 13-23-months-old had a higher probability of being underweight, and underweight and stunted compared to older and children between 6-12 months of age, respectively [13,23–26]. The later (underweight and stunted) might be related with the contamination of complementary food coupled with poor nutritionally quality, which is mainly cereal based food in Tigray region, in Ethiopia [27]. Similarly, mothers whose children were 13-18 months old were more likely to be underweight compared to those who had children between 6-12 months old, which is in line with the result found in a study conducted by Hailselassie and his colleagues [12]. The possible reasons could be, as the child becomes older his/her nutritional requirements increases, which is also supported by the extra energy expenditure related with child care, and no increase in the food intake, which is even aggravated by the decreased intake of the mother [10]. Mothers who experienced any illness in the last four weeks preceding our lent fasting survey had higher odds of being underweight compared to healthy lactating mothers, which is in line with another study conducted in Limu district of Southern Ethiopia [28]. Related with this, about one-third of the lactating mothers were living in households with non-improved water source. This was also associated with increased odds of underweight compared to mothers living in households with an improved water source for the household consumption. This is basically due to frequent illness related to water borne diseases and contamination. Illness usually affects the appetite of an individual and decreases food intake and also absorption of nutrients. It may also change the metabolism, and as a result increase the nutrient requirements

[10]. Mothers who were living with relatives' /parents grandfather was the decision maker for the income, and received aid in the form of food and/or cash and/or in kind before our fasting survey and were more likely to be underweight than mothers living in households, the income decision was her husband and not had any aid experience. The former could be due to the fact that sharing a household income to more family members or due to decreased working power and resulted in lower income, which is related with loss of father or divorce or it might be related to living in households headed by the grandfathers. This affects usually young mothers, which is associated with underweight in this study. Furthermore, it could be related to an extended family, and given the allocation of food priority given to the children, which could lead to reducing of the serving size of the meal or skipping the meal by mothers [29]. Households experiencing aid are most of the time food insecure and don't have farming land or sufficient household income, which affect quality of food of household members, especially children and women, could be the reason for the presence of more underweight women in this households. Mothers who were living in households who did not own chicken during the survey were more exposed to underweight compared to their counterparts. Earlier study in three African countries indicated that households owning livestock had lower prevalence of child stunting than those without livestock [30]. Therefore, in general promotion of animal husbandry could improve the low consumption of animal source food in the study area.

In addition to these, studies in other low and mid-income countries and Ethiopia showed that maternal educational status was a predictor for childhood wasting [13,25,31–34]. In line with this, our study confirmed that maternal illiteracy was associated with childhood wasting and stunting. Therefore, improving the education status of the mother is one of the important interventions for reduction of child undernutrition in the study district.

Maternal occupation was also one of the predictor variables of child underweight in our study. Compared to children whose mothers were housewives, children born of farmer mothers were more exposed to underweight. This could be due to high work load and absence from home, which leads to provision of less time for child care. Additionally, expending more energy on farming activity might cause poor appetite of mothers reduce the quantity and quality of breast milk produced. Beside these, children who were living in households without toilet and who were not fed colostrum after their birth were more likely to be stunted compared to those who were living in households owning toilet and did not take colostrum. The potential reason for the first case could be the infection related with pre-lacteal foods, which was associated with child stunting in a study conducted in Ethiopia [35]. Due to absence of toilet in households, open defecation increases the risk of frequent diarrhea episodes, this affects the nutritional status of children [23]. For these, promoting health education by relevant institutions on the importance of colostrum feeding during the antenatal care should be provided. Strengthening the construction of low cost latrine through the existing health extension package should be continued.

5.2. Feeding Practices and Nutrient Intake of Lactating Women and their 6-23-Months-Old Children

Ensuring the recommended diversification of diet and number of meals in a day to day life of an individual is an important component for supplying energy, macro- and micronutrients in required amount to fight against maternal and child undernutrition [1,36]. In this regard, mothers are recommended to take at least two additional meals during their lactation period, from at least five defined food groups out of ten, in a day [37,38]. Similarly, if a 6-23-months-old child eats from at least four food groups in his/her daily meals, then he/she fulfills the minimum diet diversity (MDD). This should be obtained from two or more meals (MMF) if he/she is 6–8 months old and three or more for 9–23 months for the breastfeeding children. Therefore, the minimum acceptable diet (MAD), a combination of both the MDD and MMF criterion, leads to appropriate growth and development of infant and young children [39].

In this survey, two-thirds of the mothers (65.4%) did not change the food intake during their lactation period. Even worse, one-third of lactating mothers ate less than three times during fasting period, which is lower than the expected daily three meals of a normal adult in real context. Comparable finding was observed in a study conducted in lactating women of Samre district in North Ethiopia [12]. However, the prevalence of those mothers who had less than three meals in a day was reduced to 8.4% in the non-fasting period in this survey. But, the number of meals eaten both by the fasting and non-fasting mothers were improved in the non-fasting period after the two months of lent fasting. Therefore, further study should be done for understanding how the non-fasting mothers` were affected in this regard. Likewise, three out of four children from fasting and non-fasting mothers ate the minimum number of meals recommended, during the fasting and non-fasting periods, which was in line with studies conducted in the northern and southern part of Ethiopia [40,41].

In this study, most of the mothers had a diet from a maximum of three food groups during the fasting period, regardless of their fasting status. However, the consumption of diet from more diversified food groups were increased during the non-fasting period (Chapter 2, Table 2.4). This is because the consumption of animal source foods (ASFs) and the number of meals eaten during the non-fasting period was increased. As a result, the energy, macro- and micronutrients intake were increased, although the prevalence of inadequacy of these energy and micronutrients remain higher, except iron, magnesium, vitamin B1 and niacin. However, almost all the lactating mothers and their 12-23-months-old children included in the study did not take vitamin B12, vitamin D and calcium, in both the study periods (Chapter 4, Table 4.3 and 4.4). Earlier national study in Ethiopia using blood biomarkers found that about 20% women at reproductive age were deficient of vitamin B12 [42]. However, this high discrepancy could be due to the fact that serum total vitamin B12 used for assessment can give less information to identify vitamin B12 deficiency [43,44]. Further study should be done using methyl malonic acid in urine or Holotranscobalamin in blood samples, to get more reliable information to be able to design appropriate preventive or intervention measures [43,45]. In line with our finding in the present study, there were no pregnant women ever consumed vitamin D-rich foods, fortified foods or dietary supplements, which might have resulted in vitamin D deficiency, as a serious problem, in spite of the fact that Ethiopia is located near the Equator [46]. Beside these, the highest prevalence of dietary calcium inadequacy were found in studies conducted in Gondar and Butajira districts, and at national (89-96%) level in Ethiopia [47–49]. Therefore, nutrition sensitive agriculture in both plant and livestock production should be promoted and implemented in sustainable manner, in addition to the implementation of proposed universal calcium supplementation [49].

In the present study, only 2.5% and 6.9% of the 6-23-months-old children consumed complementary foods prepared from four and more diversified food groups, in the fasting and non-fasting periods, respectively, which was lower than those found in a study conducted in the same age group of children of Orthodox mothers during the fasting period, in Gojam district of Ethiopia [50]. It was also lower than the results of studies conducted in India, Bangladesh and Vietnam, which were 38%, 48.4% and 83.2%, respectively. Furthermore, only 2.3-6.7% of the 6–23-month-old children met the minimum acceptable diet criteria in the study population, which was in line with findings for the Tigray region and national figure, in the DHS 2016 report for Ethiopia [13]. However, it was lower than that found on the 6-23-months-old children of Orthodox religion follower (8.6%) in North west Ethiopia [51]. Furthermore, the proportion of 6–23-month-old children of fasting mothers who fulfilled the criteria for MAD was lower compared to children of non-fasting mothers. It was also lower during the fasting compared to non-fasting period, which implied that the inadequate dietary micronutrients intakes were prevalent in the fasting period. In support of these, the average dietary intake of energy, protein and all micronutrients included in this study were higher in non-fasting compared to fasting period, despite the average intake of these were below the estimated need of the breastfeeding children from the complementary food and high prevalence of energy and nutrient inadequacies in the study population. For example, the prevalence of inadequate dietary intakes (<2/3 RNI) of zinc, vitamin C, energy and niacin was very high (>50%) in the 12-23-months-old children, followed by protein, iron, vitamin A and vitamin B1 (20-50%), respectively. Studies conducted in Amhara and Tigray regions, and at national level in Ethiopia confirmed that zinc and vitamin A deficiencies are high in children [52,53]. Another study conducted in three other African countries and Ethiopia also revealed that anemia, vitamin A and zinc deficiencies are public health problems in these countries [54]. The prevalence of dietary inadequacy (2/3 RNI) of Vitamin C was high in both the children and lactating mothers and almost steady in both study periods. This can indicate that low consumption of vitamin C rich foods is the chronic problem in the study area, which might be related with the low consumption of fruits, animal source foods including dairy products, root crops like potato, anchote in the study area [10,22]. Therefore, consumption of vitamin C rich foods should be promoted to improve the bioavailability of minerals. This alone can't be enough, unless a traditional processing techniques is used to improve the bioavailability of iron, zinc and calcium, in a population, in which cereals and legumes are the main staple foods and a source of energy and most of the nutrients needed for an individual (Chapter 2, Table 2.4). Beside these, the proportion of mothers who consumed more cups of coffee was higher in the fasting than non-fasting period, in the whole study population, and these were due to higher proportion of the non-fasting mothers included in this study who took significantly more coffee in the fasting than non-fasting periods. However, the reason for less consumption for the fasting mothers could be related to some Ethiopian Orthodox religion monarchist, who preached to followers not to consume coffee during fasting periods. Therefore, moderate intake of coffee, coupled with discouraging intake close to meals to be eaten should be done, otherwise, it could also reduce their bioavailability, leading to increased risk of micronutrient deficiencies, especially of iron, calcium, and zinc [55].

5.3. CIMI: A Promising Dietary Assessment Application for Rural Ethiopian Population

Assessing the dietary pattern of an individual, and a community at large, is the fundamental for setting an appropriate prevention and intervention activities in a given country. It can also help to identify, both poor and good dietary habits, and identify the extent of risk and deficiency for specific nutrients in a certain community, by the practitioners, researchers and development agencies [56]. As a result, qualitative and quantitative dietary intake data have been collected using dietary assessment techniques, which have been developed and implemented globally. However, most of the quantitative dietary assessment methods are time consuming, need an experienced and well trained data collectors, and an expert to calculate the energy and nutrient intakes using software before identifying extent of the nutritional problem in the study population. Thus, quantitative dietary assessment methods are less applicable in developing countries like Ethiopia, where more than three-fourth of the population are living in rural poor settings, which most often leads to less availability of quantitative dietary data [57]. In this study, a web-based nutritional assessment application called Calculator for Inadequate Micronutrient Intake (CIMI), which is simple, easy-to-use and informative and consider the 93 commonly consumed Ethiopian foods was adapted for Ethiopian population and validated against internationally established nutrition assessment software called NutriSurvey (NS). Accordingly, the average intake values of energy, protein and most nutrients produced by CIMI and NS were almost similar, for the lactating women and their 12-23-months-old children, regardless of the two study periods. Exceptions were observed in vitamin A in both women and children, and vitamin C only in the lactating women, which were higher in NS and CIMI, compared to the results produced by CIMI and NS, respectively. The findings on the vitamin A was in line with the result found in the validation study of Indonesian CIMI [58]. The reason for the vitamin A in our case was, the butter and oil food group in CIMI has got a lower average vitamin A content compared to the fortified palm oil consumed by almost all of the study households surveyed during the fasting and non-fasting periods. The consumption of different oil types in the district depends on the availability of oil types through the cooperatives provided under the massive import by the subsidy of the Ethiopian government and the distribution through the aid in the district. To solve the problem related with vitamin A, deselection of the unconsumed oil type in the oil and butter food will be important in future CIMI use. The increased result produced in the vitamin C was due to the greater share of the tomato (43.8%) for the ‘other vegetables` food group in the CIMI and its relatively high vitamin C content, but less consumed compared to the highly consumed cabbage by the adults in the study area. The average intakes of protein, iron and calcium produced by CIMI were also higher than NS in both the study groups, which was related with the consumption of high amount of peas, despite its share in the ‘beans` food group is small (12.4%). The other reason was the higher contents of protein, iron and calcium in the food items compared to peas, which created the ‘beans’ food group. Furthermore, if the amount to be set up between the two sliders gets larger, then the consumption is increasing in most of the food groups created the CIMI. The selection of the lower or upper, where the amount consumed in the group fails depends on the nearest amount in the setup of the sliders, which also affects the beans group. Therefore, if the amount approaches to the upper slider, then automatically the upper slider will be selected and this will lead to overestimation of intake of specific nutrients compared to NS, otherwise underestimate for lower slider selection. Similarly, the average intake results produced for magnesium in the pepper and vitamin B1 and egg food groups were overestimated by selecting the upper slider during the data entry of CIMI in the higher proportion of an individual. The vitamin B6 was also slightly higher in results produced by CIMI, which was due to the fact that Ethiopian kale, which was less consumed in the study area, but contributed much (58.4%) to the ‘green leaves’ food group overestimated the average intake in the study groups, regardless of the study periods.

The results in the present study also showed that the proportion of lactating women and the 12-23-months old children who were identified as having inadequate intake of energy and most nutrients (<2/3 RNI) were similar by CIMI and NS, in the study periods. Like the average intake for the vitamin A of the lactating women and the 12-23-months-old children, and vitamin C for the lactating women group, the prevalence identified by the CIMI and NS was also variable, in both the study periods. The reasons for these discrepancies are also similar with those earlier stated for the average differences for vitamin A and vitamin C intakes in our study. Additionally, according to criteria set by Lambert and her colleagues (2018), the results of vitamin A for both of the study groups, magnesium for the 12-23-months-old children and vitamin B6 for the lactating women, were produced by CIMI had moderate accuracy compared to NS. Similarly, the accuracy of results produced by CIMI of the vitamin B6 in the 12-23-months-old children and vitamin C for the lactating women were low. The reason for the vitamin B6 was due to the actual small average values produced, so that the small mean differences in few individuals between CIMI and NS dramatically increased the mean difference %, which is the drawback of the accuracy classification method we used. Whereas, the vitamin C was due to the reasons mentioned for the discrepancies observed in the average results produced. Despite these, the intake of energy, protein and most micronutrients, for both of the study groups, in both study periods were calculated either in good or very high accuracy by CIMI. Beside these, strong correlations were found between CIMI and NS results in all the nutrients and energy for the 12-23-months-old children (R=0.741-0.956) and lactating women (R=0.779-0.920) (Chapter 4, Figure 4.1 and 4.2). Our results found in the correlation analysis of results produced by NS and CIMI for energy, protein, iron, zinc and vitamin A in both the study groups were higher than previous study in Indonesian children and women, except that of energy for lactating women. This discrepancy could be related to the smaller sample size of the study participants compared to this study. Additionally, the correlation coefficients of all nutrients, except energy in our study were higher than those found in a CIMI trial conducted on Tanzanian women [59]. Thus, CIMI developed for rural Ethiopian population calculates the average nutrient intake accurately, and identifies the inadequate micronutrient intake of individuals using FAO/WHO recommendation for nutrient intake (RNI).

Unlike other dietary assessment methods, CIMI provides result immediately after the interview is completed, which allows the enumerator to provide direct feedback to the interviewee to improve the dietary habits considering the socio-cultural and economic status of the community, and the potential crops available in the farm and market of the district. Currently, most of the dietary quality information have been collected using the qualitative method called diet diversity score, which is a proxy indicator at the individual and household levels, in most of the developing countries, as most of the quantitative assessment methods are not feasible in these countries [38]. In this technique, the principal focus is assessing the diversity of the standardized food groups consumed in the diet and quantifying in to the score to indirectly predict the micronutrients adequacy in general, using an established cutoff points mentioned earlier. Therefore, the information that can be produced from this method is limited unless an alternative method is used to identify specific nutrient deficiency in the given community. Considering these, CIMI can replace the diet diversity, by producing much more results on the diet quality of an individual, and solving the problems that can be encountered by diet diversity assessment method. In situations where the diet diversity and other quantitative dietary assessment methods are not appropriate, CIMI can be also used in cross-sectional and/or longitudinal/intervention studies. Cumulative analysis of individual results, can be used in mapping nutrition situation of a given district or country using the GPS information to be produced during the survey carried out by CIMI. Therefore, appropriate and specific prevention or intervention activities can be planned and done timely. Therefore, our results indicate that, the CIMI developed for Ethiopian population using the commonly consumed Ethiopian foods are applicable in rural setting, where 85% of the population is living and suffering from multiple malnutrition problems. In general, the use of CIMI is wider, which covers from the simple cross-sectional study in a certain area to the complex longitudinal study at the national level in Ethiopia.

5.4. Conclusion

Based on our findings on the anthropometric measurements of lactating women and their 6-23-months-old children, maternal and child undernutrition is a serious public health problem in the study district. But, it was lower than the prevalences of undernutrition in children and women at the reproductive age group (15-49 years) reported in the Ethiopian Demographic and Health Survey (2016) for Tigray region, where this study was conducted. Therefore, these indicated that the nutritional status of women and their children in the Tigray region was improving, despite the unacceptable higher prevalences of undernutrition in fasting mothers (underweight) and children (stunting, underweight and wasting) born of these fasting mothers and the study population especially during the Ethiopian Orthodox lent fasting period. Mother fasting status during pregnancy and lactation periods of the indexed child was amongst the predictor variables of the undernutrition for the lactating women and their 6-23-months-old children in the study population. Thus, the existing maternal and child nutrition intervention activities should consider religious fasting periods. Mothers who were young, had sickness within four weeks preceding the fasting period, and children between 13 and 18 months of age were more exposed to maternal underweight. Mothers who were living in the households whose decision makers were grandfathers, received aid, not owning chickens and had no access to water were also associated with maternal underweight. Therefore, households with younger mothers and non-improved water sources should get priority in nutritional intervention. Furthermore, promoting chicken husbandry, and improving the WASH in the community may also improve the low consumption of animal source foods and reduce maternal undernutrition in the study district. Likewise, maternal education and occupational status, child age, colostrum intake status, in addition to toilet presence in the household where the child was living associated with child undernutrition in the study district. Therefore, improving the maternal education, reducing the work burden in farming activities and/or supporting of mothers in non-farm income generating nearby by their living residence, household latrine coverage and breastfeeding of colostrum should be promoted and strengthened. The number of meals eaten, both by the lactating women and their 6-23-months-old children are below the recommendation, from the less diversified food groups. These food groups are mainly from the cereals and legumes, which are known to have high amount of phytic acid and tannin which limit the absorption of minerals and protein by chelating with it. In addition to the low consumption of all other food groups, by both the study groups in the study population, the proportion of fasting lactating women and their 6-23-months-old children who consumed animal source foods (dairy, meat, poultry and fish) were very low compared to the lactating women and their 6-23-months-old in the non-fasting group. Similarly, the consumption of animal source foods was affected during the lent fasting than non-fasting period at the study population level. This sub-optimal dietary pattern was synergized with more cup of coffee consumption by the lactating women, and even worst in the lent fasting period. Furthermore, we also concluded that the prevalence of inadequate intakes (<2/3 RNI) of dietary energy and most micronutrients, except protein and magnesium are high in the 12-23-months-old children. Similarly, the proportion of lactating women who did not take adequate amount of vitamin A, calcium, vitamin B6, vitamin B12, pentatonic acid and vitamin C were also high. These high prevalences of inadequacy was more affected during the lent fasting period, in both the young children and lactating women. Thus, activities which will improve the diet diversity by incorporating the nuts and seeds, dark green leafy vegetables, vitamin A and C rich fruits and animal source products, and increasing the meal frequency, for both the lactating women and children should be done urgently. Besides these, use of traditional processing techniques like dehulling/dehusking, soaking and germination, and slightly roasting are crucial during preparation of food for the nutrient needy groups like lactating and pregnant women, and their young children. Additionally, moderate intake of coffee after some hour interval of meal to be eaten should be promoted to increase the absorption of non-heme iron from plant source foods. Shockingly, the intake of the vitamin B12, vitamin D and calcium by almost all the lactating women and their 12-23-months-old children were below the recommended intake (2/3 RNI) from their diet in the 24-hr preceding the fasting and non-fasting surveys. Thus, implementation of the proposed universal calcium supplementation in Ethiopia, in addition to urgent investigation and appropriate other public health nutrition activities should be done in the district. In general, the activities which will focus on the dietary improvement (quality and quantity) should get more priority, and special attention should be given for fasting periods.

We also concluded that, the Calculator for Inadequate Micronutrient Intake (CIMI) adapted using commonly consumed Ethiopian foods for rural Ethiopian population estimates the average nutrient intake accurately. CIMI also identifies the individual inadequate intake of energy, macro- and micronutrients using the FAO/WHO recommended nutrient intake (RNI) immediately after the interview. Therefore, this feature enables the interviewers to give immediate feedback and suggest context based dietary improvements for the interviewee. CIMI can also replace the DDS by solving the problem encounter by this technique and producing more quantitative results to design specific nutrition intervention. It can be also used in cross-sectional and/or longitudinal and/or intervention studies, where the DDS and other quantitative dietary assessment techniques are not appropriate. In general, CIMI can be used in Ethiopia, as a simple dietary assessment tool for nutrition and related researchers, policy makers, implementers and evaluators.

5.5. References

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6. Summary

Religious fasting is one of the categories of dietary or food taboos, which may affect the dietary intake and nutritional status of individuals. In Ethiopia, about half of the population are followers of Ethiopian Orthodox Tewahedo religion, and approximately 250 days per annum are fasting days. In these fasting days, lactating and pregnant women and children are exempted from fasting. However, lactating and pregnant women fast and are not also happy to prepare non-fasting foods for their children during the fasting days due to fear of contamination of family food.

Early identification of micronutrient deficiencies in Ethiopia are flouted, as most often the quantitative dietary data are not available. As a result, the hidden hunger might have not been addressed properly, where it remains high and persistent. Therefore, easy to use, less costly and applicable assessment tool which can estimate the quantitative dietary intake of an individual or a community is urgently needed to achieve the national and international goals set for eradicating malnutrition. The Calculator for Inadequate Micronutrient Intake (CIM) is a simple, easy-to-use, informative, web-based application of quantitative dietary assessment method, which was first developed in Indonesia for Indonesian population. It estimates energy and nutrient intake correctly, and identifies nutrient inadequacy according to FAO/WHO recommended nutrient intake (RNI) regarding age, sex and physiological stage. Thus, the present study was conducted with the aim of assessing and comparing the nutritional status and dietary intake of lactating women and their 6-23-months-old children in fasting and non-fasting periods, and to adapt and validate the CIMI program for Ethiopian population.

This study was conducted in rural Genta Afeshum district, in Tigray, Ethiopia, where almost all people in the woreda are followers of Ethiopian Orthodox Christianity. A longitudinal study was conducted using575 and 522 lactating women and their 6-23-months-old children in the lent fasting and non-fasting.

In the present study it was found out that the prevalence of underweight (BMI < 18.5 kg/m^2) in fasting lactating women was high (50.6%) which is associated with maternal age, maternal illness within four weeks preceding the fasting survey, fasting status during their pregnancy and lactation period of their children included in this study. Additional predictor variables for maternal underweight were grandfathers' as household decision maker, use of non-improved water source, household aid experience and the absence of chicken in the household. The average number of meals, diet diversity, and animal source foods consumption scores were significantly higher in non-fasting compared to fasting periods, regardless of the fasting status ($p < 0.001$, $p < 0.05$ and $p < 0.001$, respectively). Whereas, 31.6–33.7%, 11.7–15.7% and 4.4–4.8% of the 6-23-months-old children in the study population were stunted, underweight and wasted, respectively. In the fasting period, the weight-for-length (WLZ) and length-for-age (LAZ) values for the 6-23-months-old children of non-fasting mothers were significantly higher ($p < 0.05$) than the children of the fasting mothers' group. Similarly, the median weight-for-age (WAZ) and diet diversity score (DDS) of children of fasting mothers were also significantly lower in fasting compared to non-fasting period. The proportion of the 6-23-months-old children who met the minimum acceptable diet (MAD) was small (2.3-6.7%) in the study population; however, this proportion was significantly ($p < 0.001$) higher in the non-fasting than fasting period in the children of fasting mothers. Age of the child, maternal fasting status during pregnancy and lactation periods, maternal education and occupation were associated with child underweight. Likewise, age of the child, colostrum intake status, maternal fasting status during pregnancy and lactation period and toilet presence in the household were associated with child stunting. But, maternal fasting status during lactation period and maternal education predicted wasting in the children precisely. The average energy, protein and almost all micronutrients intakes of children and women were lower in fasting compared to non-fasting period. At the same time, the prevalence of inadequate intakes of energy, protein and most micronutrients were higher in both the children and lactating women during fasting than non-fasting period. The result of this study revealed that the correlation coefficients for the average dietary nutrient intake calculated by CIMI and the reference software NutriSurvey (NS) were between 0.741-0.956 for the children and between 0.779-0.920 for the lactating women groups. As a conclusion, the dietary pattern and nutritional status of lactating women and their breastfed children are affected during the fasting period. Therefore, the existing multi-sectoral nutrition intervention strategies in Ethiopia should include religious institutions in a sustainable manner. CIMI adapted for the rural Ethiopian setting estimates the average nutrient intake accurately; and identifies inadequate micronutrient intake of individuals enabling enumerators to provide feedback and suggest improvements. Thus, CIMI can be used in Ethiopia, as a simple dietary assessment tool by nutrition and related researchers, policy makers, implementers and evaluators.

Zusammenfassung

Beim religiösen Fasten werden Lebensmitteltabus praktiziert, die die Nährstoffaufnahme und den Ernährungszustand eines Individuums beeinflussen können. In Äthiopien besteht etwa die Hälfte der Bevölkerung aus äthiopisch-orthodoxen Anhängern der Tewahedo-Religion. In dieser Religion wird an ungefähr 250 Tagen im Jahr gefastet, wobei stillende und schwangere Frauen und Kinder vom Fasten ausgeschlossen sind. In der Regel wird das Fasten jedoch auch von laktierenden und schwangeren Frauen praktiziert, und diese Frauen bereiten ihren Kindern während der Fastentage nicht gerne tierische Lebensmittel zu, aus Angst, das Familienessen zu „verunreinigen".

Die frühzeitige Erkennung von Mikronährstoffmängeln in Äthiopien scheitert meist an der mangelnden Verfügbarkeit von quantitativen Daten zur Nährstoffaufnahme. Infolgedessen wird der verborgene Hunger nicht richtig wahrgenommen und bekämpft, wodurch er dauerhaft und in einer hohen Prävalenz auftritt. Um die nationalen und internationalen Ziele zur Beseitigung der Unterernährung zu erreichen, ist ein einfaches, kostengünstiges und praktisch anzuwendendes Erhebungsinstrument mit dem die quantitative Nährstoffaufnahme einer Einzelperson oder einer Gemeinschaft geschätzt werden kann, dringend erforderlich. Der Calculator for Inadequate Micronutrient Intake (CIMI) ist eine simple, benutzerfreundliche, informative App zur quantitativen Ergebung der Micro- und Makronährstoffzufuhr, deren Vorläuferversion für die indonesische Bevölkerung entwickelt wurde. CIMI schätzt die Energie- und Nährstoffaufnahme korrekt ein und identifiziert gemäß der FAO / WHO empfohlenen Nährstoffzufuhr (RNI) eine unangemessen niedrige Nährstoffaufnahme in Bezug auf Alter, Geschlecht und Schwangerschaft/Stillzeit.

Ziel der vorliegenden Studie war die Erfassung und Beurteilung des Ernährungsstatus und der Nahrungsaufnahme laktierender Frauen und ihrer 6-23 Monate alten Kinder in Fasten- und Nicht-Fastenzeiten. Desweiteren sollte das CIMI-Programm an die äthiopische Bevölkerung angepasst und dessen Anwendbarkeit untersucht werden.

Diese Studie wurde im ländlichen Bezirk Genta Afeshum in Tigray, Äthiopien durchgeführt, in dem fast alle Menschen Anhänger des äthiopisch-orthodoxen Christentums sind. Es handelte sich um eine longitudinale Studie an der 575 und 522 stillende Frauen und ihre 6-23 Monate alten Kinder während einer Fasten- und einer Nicht-Fastenperiode teilnahmen.

Die vorliegende Studie ergab, dass die Prävalenz von Untergewicht (BMI <18,5 kg / m^2) bei fastenden laktierenden Frauen hoch war (50,6%). Diese hohe Prävalenz an Untergewicht war mit dem mütterlichen Alter, einer Erkrankung der Mutter innerhalb von vier Wochen vor der Befragung, des Fastens während der Schwangerschaft und der Stillzeit ihrer in diese Studie eingeschlossenen Kinder assoziiert. Weitere Prädiktoren für ein mütterliches Untergewicht waren Großväter als Entscheidungsträger im Haushalt, die Verwendung einer unsicheren Wasserquelle, der Erhalt von Haushaltshilfen und das Fehlen von Hühnern im Haushalt. Die durchschnittliche Mahlzeitenanzahl, die Nahrungsvielfalt und der Konsum von tierischen Lebensmitteln war in der Nicht-Fastenperiode signifikant höher ($p < 0{,}001$, $p < 0{,}05$ bzw. $p < 0{,}001$), unabhängig vom Fastenstatus. Dem gegenüber waren 31,6–33,7%, 11,7–15,7% und 4,4–4,8% der 6-23 Monate alten Kinder in der Studienpopulation zu klein für ihr Alter, untergewichtig und zu leicht für ihr Alter. In der Fastenperiode waren die Werte für das Gewicht für die Körpergröße (WLZ) und für die Größe des Alters (LAZ) für die 6-23 Monate alten Kinder nicht fastenden Müttern signifikant höher ($p < 0{,}05$) als die Kinder der Gruppe der fastenden Müttern. In ähnlicher Weise waren auch der Median des Altersgewichts (WAZ) und des Diet Diversity Scores (DDS) der Kinder von fastenden Müttern während der Fastenperiode signifikant niedriger als im fastenfreien Zeitraum. Der Anteil der 6-23 Monate alten Kinder, die die akzeptable Mindestdiät (MAD) verzehrten, war in der Studienpopulation gering (2,3-6,7%). Bei Kindern von fastenden Müttern war dieser Anteil jedoch in der Nicht-Fastenphase (n <p <0,001) signifikant höher als in der Fastenzeit. Das Alter des Kindes, der Fastenstatus der Mutter während der Schwangerschaft und Stillzeit, die Bildung und Beschäftigung der Mutter waren mit kindlichem Untergewicht assoziiert. Ebenso waren das Alter des Kindes, die Kolostrumgabe, der Fastenstatus der Mutter während der Schwangerschaft und Stillzeit und die Verfügbarkeit einer Toilette im Haushalt mit Stunting verbunden. Der Fastenstatus der Mutter während der Stillzeit und die Bildung der Mutter sagten das Risiko für ein zu geringes alterspezifisches Körpergewicht des Kindes präzise voraus. Die durchschnittliche Zufuhr an Energie-, Eiweiß- und fast aller Mikronährstoffe von Kindern und Frauen waren im Vergleich zu Nicht-Fastenzeiten niedriger. Gleichzeitig war die Prävalenz einer unzureichenden Zufuhr von Energie, Eiweiß und den meisten Mikronährstoffen sowohl bei Kindern als auch bei stillenden Frauen während des Fastens höher als bei Nicht-Fasten. Das Ergebnis dieser Studie zeigt, dass die von CIMI und der Referenzsoftware Nutrisurvey (NS) berechneten Korrelationskoeffizienten für die durchschnittliche Nährstoffaufnahme zwischen 0,741-0,956 bei Kinder und 0,779-0,920 bei laktierenden Frauen lagen.

Zusammenfassen lässt sich sagen, dass durch das Fasten das Ernährungsmuster und der Ernährungszustand von stillenden Frauen und deren Kindern während der Fastenzeit betroffen ist. Daher sollten in Äthiopien religiöse Institutionen in multisektorale Ernährungsinterventionen einbezogen werden. CIMI, angepasst an die ländliche äthiopische Ernährungsweise, schätzt die durchschnittliche Nährstoffaufnahme präzise ein und identifiziert eine unzureichende Mikronährstoffaufnahme von Individuen, die es Enumeratoren ermöglicht Feedback zu geben und Verbesserungen vorzuschlagen. Daher kann CIMI in Äthiopien als einfaches Instrument zur Beurteilung der Ernährung von Wissenschaftlern, politischen Entscheidungsträgern und Mitarbeitern von Ernährungserhebungen und -interventionen verwendet werden.

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Affidavit

Annex 2 to the University of Hohenheim doctoral degree regulations for Dr. rer. nat.

Affidavit according to Sec. 7(7) of the University of Hohenheim doctoral degree

regulations for Dr. rer. nat.

1. For the dissertation submitted on the topic

Dietary Intake, Nutritional Status of Lactating Women and their 6-23-Months-Old Children in Genta Afeshum District, Rural Ethiopia; Development and Validation of Calculator for Inadequate Micronutrient Intake (CIMI)

I hereby declare that I independently completed the work.

2. I only used the sources and aids documented and only made use of permissible assistance by third parties. In particular, I properly documented any contents which I used- either by directly quoting or paraphrasing - from other works.

3. I did not accept any assistance from a commercial doctoral agency or consulting firm.

4. I am aware of the meaning of this affidavit and the criminal penalties of an incorrect or incomplete affidavit.

I hereby confirm the correctness of the above declaration: I hereby affirm in lieu of oath that I have, to the best of my knowledge, declared nothing but the truth and have not omitted any information.

Place and Date Signature

Curriculum Vitae

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- BSc student in Rural Development and Family Sciences (2007-2010)

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Publications

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